POWER MARKET STUDY

OF

ICELAND

By the

HARZA ENGINEERING COMPANY INTERNATIONAL

Prepared for

THE STATE ELECTRICITY AUTHORITY

GOVERNMENT OF ICELAND

NOVEMBER 1963

POWER MARKET STUDY

OF

ICELAND

By the

HARZA ENGINEERING COMPANY INTERNATIONAL

Prepared for

THE STATE ELECTRICITY AUTHORITY

GOVERNMENT OF ICELAND

NOVEMBER 1963

GENERAL CONTENTS

SUMMARY LETTER

DETAILED TABLE OF CONTENTS

THE REPORT

THE EXHIBITS

THE TABLES

THE SUMMARY LETTER

HARZA ENGINEERING COMPANY INTERNATIONAL
CONSULTING ENGINEERS
RIVER PROJECTS

OFFICES
TEHRAN, IRAN
SAN SALVADOR, EL SALVADOR
LAHORE, WEST PAKISTAN
AMMAN, JORDAN
MANILA, PHILIPPINES
BUENOS AIRES, ARGENTINA
SAN PEDRO SULA, HONDURAS
REPRESENTED IN THE UNITED STATES BY
HARZA ENGINEERING COMPANY
CHICAGO, ILLINOIS

CABLE ADDRESS "HARZINT"
ADDRESS REPLY TO
HARZA ENGINEERING COMPANY
FOR THE ACCOUNT OF
HARZA ENGINEERING COMPANY INTERNATIONAL
400 WEST MADISON STREET
CHICAGO 6, ILLINOIS
TELEX NUMBER 312-222-9334

November 25, 1963

POWER MARKET STUDY OF ICELAND

SUMMARY OF REPORT

The State Electricity Authority
P. O. Box 40
Reykjavik, Iceland

Gentlemen:

We are pleased to present our Report on the Power Market Study of Iceland, authorized by your verbal request of September 26, 1963. This Report contains a summary of the engineering investigations and studies resulting in our forecast of annual power and energy requirements of the entire nation for the twenty-year period ending with 1982.

For purposes of this study, Iceland was divided into four market areas designated: Southwest, Northern, Northwest, and Eastern, as shown on Exhibit 1 of the main Report. These divisions were based largely on geography and cultural development as they have affected and will continue to affect power loads. At the present time, about three-fourths of the power loads are in the more heavily populated Southwest which contains the metropolitan area of Reykjavik. The Northern Area, containing Akureyri, has about fifteen percent of the total national load. Loads in the other two areas are about equal, and each represents about four percent of the national total. Insofar as present types of loads are concerned, our forecasts indicate that the relative regional distribution of the total load will continue about as at present. However, the location of a large industrial load, such as an aluminium smelter, would change this relative distribution. A smelter would locate either in the Southwest near Reykjavik, or in the Northern area near Akureyri. A single potline would require about 55 megawatts of installed capacity. This would about triple 1968 loads in the Northern area or, alternatively, increase the Southwest load by about one-half.

Our power market analyses and forecast were aided greatly by the excellent statistical data available in Iceland, especially with respect to the past and present production and consumption of electricity in the four areas of the country. The detail and completeness of these data were unparalleled in our experience. They formed a principal basis for our analyses of present and likely future conditions important to our forecasts of electrical power and energy production requirements.

Our studies were also aided greatly by the cooperation of the staff of the State Electricity Authority and of engineers of the Municipal Utilities and the NATO base. Further, our understanding of the Iceland power situation resulting from our extensive studies over the past six years of water resources development in Iceland contributed substantially to our power market analyses. The studies are presented in detail in the main text of this Report.

Our estimates of annual power and energy requirements for each of the four areas of the country are on a production basis. Thus, customer consumption, losses, and self-use are included in the values presented. Further, the forecasts assume ample availability of generating resources in advance of load.

The maximum primary power production in megawatts (MW) for 1962 and our estimates for selected subsequent years within the twenty-year forecast period are summarized from the detail of the main body of the Report, as follows:

Estimated Peak Generation - Megawatts

Year:	1962	1967	1968	1972	1977	1982
SW Area	79	103	113	150	206	279
N Area	16	21	23	29	41	54
NW Area	4	7	7	10	12	15
E Area	4	6	7	9	14	19
Subtotal (MW)	103	137	150	198	273	367
For Proposed Aluminium Plant (MW)	-	-	55	55	55	55
Primary Production (MW)	103	137	205	253	328	422

A corresponding tabulation for primary energy production in million kilowatt hours (GWH) is as follows:

Estimated Energy Production - Gigawatt Hours

Year:	1962	1967	1968	1972	1977	1982
SW Area	387	515	556	743	1025	1363
N Area	83	108	114	142	188	251
NW Area	18	29	31	40	52	63
E Area	13	23	25	37	55	77
Subtotal	501	675	726	962	1320	1754
For Proposed Aluminium Plant	-	-	470	470	470	470
Primary Production	501	675	1196	1432	1790	2224

The various areas might, in some degree, be interconnected ultimately by transmission lines. Our studies indicate the desirability of an interconnection early in the forecast period between the Southwest and Northern areas such that operation would combine these two areas into one. Almost complete transmission interconnection of presently separate load centers within the Northern area was assumed in the forecasts. The interconnection would be essential if the new power resource to supply an aluminium smelter at Akureyri consisted of a single large hydroelectric plant located in the Southwest area, and which would also serve increases in load in its home area. The proposed Burfell Project is such a power plant. Even without a smelter load at Akureyri, it may be more economic to supply future loads in the Northern Area by transmission from the Southwest instead of by a relatively small new hydroelectric plant in the North. At some time within the forecast period it may be attractive economically to provide power supply by a transmission interconnection from the Northern to the Eastern area, where attractive small hydropower sites appear to be few. This procedure does not now appear to be appropriate with respect to the Northwest area, where loads are small and scattered and the terrain is difficult.

Our estimates of power and energy primary production requirements for the proposed Southwest-Northern integrated system are summarized below:

Estimated Power Demand and Energy Production - Integrated SW-N Areas

Year:			1962	1967	1968	1972	1977	1982
Combined System Primary Production Without Aluminium								
Plant:	Power	(MW)	95	124	136	179	247	333
	Energy	(GWH)	470	623	670	885	1213	1614
Combined System Primary Production With Aluminium								
Plant:	Power	(MW)	95	124	191	234	302	388
	Energy	(GWH)	470	623	1140	1355	1683	2084

The values presented in the three tabulations above do not include the secondary portion of the energy used by the fertilizer plant located in the Southwest area. These additional requirements are estimated to be 17.0 MW of capacity and a maximum of 149 GWH of energy per year when surplus hydro capacity is available.

The provision of specific power sources to supply the forecast loads for each area or combined areas has, in general, been beyond the scope of this Report. Moreover, power plant capacities in the Northwest and Eastern areas would be greater than the indicated power demands because of lack of transmission interconnections to all the power plants within each area, until such interconnections may be complete.

However, the interconnection of the Southwest and Northern areas permit the forecasts to be related directly to total power plant capability. On the assumption that all present power sources, thermal and hydro, will be available to load, the studies reveal that the expected demand in the Southwest-North integrated system will approach its firm capability in 1967. This assumes the addition of the new Ellidaár steam unit in 1965. Accordingly, it would be necessary to add further capability by 1968 in order for the expected demand to not exceed firm capacity. Construction would need to start very soon on a hydroelectric plant in order to assure completion by 1968.

The load increase for the Southwest-North integrated system between 1967 and 1972 is 55 MW, as shown by the above tabulation. The addition of an aluminium smelter would double that amount. This total load would absorb the proposed first stage of the Burfell project consisting of three 35 MW units. The subsequent installation of three additional units in three successive stages is estimated to maintain the system firm capacity above the load until about 1978.

In following a program of suitably planned stages of Burfell development to meet the peak requirements of a SW-N integrated system, there will be ample combined capability to supply the primary load as well as to provide a substantial amount of surplus energy.

Very truly yours,

HARZA ENGINEERING COMPANY
INTERNATIONAL

E. Montford Fucik
President

DETAILED TABLE OF CONTENTS

DETAILED TABLE OF CONTENTS

Chapter		Page
	SUMMARY LETTER	1
	DETAILED TABLE OF CONTENTS	i
I	INTRODUCTION	I-1
II	GENERAL	II-1
	Geography	II-1
	Population and Occupations	II-1
	Natural Resources	II-2
	Climatic Conditions	II-3
	Industries	II-4
III	THE ELECTRIC SUPPLY INDUSTRY	III-1
	Degree of Electrification	III-1
	Segregation of the Country for Power Development Studies	III-1
	Electrical Development in the SW-Area	III-3
	Electrical Development in Other Areas	III-4
	Privately Owned Power Plants	III-4
	Installed Generating Capacity	III-5
	Production of Electricity	III-6
	Electricity Rates	III-7
	Alternative Costs	III-8
	Future Sources of Power Supply	III-8
IV	GENERAL USE OF ELECTRICITY	IV-1
	Consumption Per Capita	IV-1
	Cooking and Heating	IV-1
	Refrigeration	IV-2

DETAILED TABLE OF CONTENTS (cont'd.)

Chapter		Page
IV	GENERAL USE OF ELECTRICITY (cont'd.)	
	Industrial Use	IV-3
	Rural Use	IV-4
	Illumination	IV-4
V	ELECTRIC SUPPLY AGENCIES	V-1
	Municipal Electric Utilities	V-1
	The State Electricity Authority	V-2
VI	SPECIFIC USE OF ELECTRICITY	VI-1
	Energy Used By Ordinary Electricity Consumers	VI-1
	Power and Energy Used By the NATO Base	VI-2
	Electricity Supply to the Fertilizer Factory	VI-3
	Power and Energy Requirements of the Cement Factory	VI-5
VII	EXISTING ELECTRIC SYSTEMS	VII-1
VIII	POSSIBLE FUTURE INTERCONNECTIONS	VIII-1
IX	FORECAST OF FUTURE POWER AND ENERGY REQUIREMENTS	IX-1
	Southwest Area	IX-2
	Northern Area	IX-5
	Northwestern Area	IX-7
	Eastern Area	IX-9
X	FORECAST FOR THE SW-N INTEGRATED SYSTEM	X-1
XI	SUMMARY AND CONCLUSIONS	XI-1

DETAILED TABLE OF CONTENTS (cont'd.)

EXHIBITS

1. Inhabited Areas of Iceland and Degree of Electrification

2. Population, Electrical Energy Production and Consumption Per Capita

3. Electric Utilities - State and Municipal

4. Power Stations, Transmission Lines and Main Sub-Stations

5. Possible Future Interconnections

6-A (SW-N) Integrated System; Forecasted Demand and Possible Plant Installation Schedule

6-B (SW-N) Integrated System; Forecasted Energy Production Requirements and Average Hydro Capability

TABULATIONS

I Southwest - Statistics of Energy Consumption

II Southwest - Load Statistics

III Southwest - Actual and Projected Energy Production, Maximum Demand and Load Factor

IV North - Statistics of Electricity Consumption and Production

V North - Actual and Projected Electricity Sales, Production and Load Factor

VI Northwest - Statistics of Electricity Consumption and Production

VII Northwest - Actual and Projected Electricity Sales, Production and Load Factor

VIII East - Statistics of Electricity Consumption and Production

IX East - Actual and Projected Electricity Sales, Production and Load Factor

X Southwest - North Integrated System; Forecast of Energy Production, Maximum Demand and Load Factor

THE REPORT

I Introduction

II General

III The Electric Supply Industry in Iceland

IV General Use of Electricity

V Electric Supply Agencies

VI Specific Use of Electricity

VII Existing Electric Systems

VIII Possible Future Interconnection

IX Forecast of Future Power and Energy Requirements

X Forecast for the SW-N Integrated System

XI Summary and Conclusions

Chapter I

INTRODUCTION

The purpose of the study presented in this Report is to review the development of the electricity supply industry in the various areas of Iceland; to examine the extent of use and trends in the consumption of electricity by the various classes of consumers; to survey the future market for electricity; and, based on an adequate supply of electricity being available, to forecast the production requirements of power and energy for a twenty-year period ending with 1982.

In addition to the provision of specific data directly connected with the future estimates of electricity requirements, an attempt has been made to include in this Report, sufficient related general information so as to provide any reader with the necessary background underlying the assumptions made herein and the conclusions reached.

Chapter II

GENERAL

Geography

Iceland has an area of 103, 022 square kilometers, with a length from east to west of 490 kilometers and a breadth from north to south of 312 kilometers. The extreme northern portion practically touches the Arctic Circle.

The greater part of Iceland consists of a highland plateau at elevations ranging between 400 and 800 meters. Above this plateau rise higher mountain ranges and single mountain peaks. Numerous valleys intersect the highland, but continuous lowland areas are only found in a few places along the coast. The inhabited areas rarely reach higher than 200 meters above sea level and vegetation does not extend above 800 meters. Of the whole country, only 23 percent has vegetation and the remainder is made up of glaciers and barren land. Only about 1000 square kilometers, or one percent of the area of Iceland, is under cultivation.

Population and Occupations

Population statistics are compiled annually in Iceland and the total number of inhabitants on December 1, 1962 was 183, 478. About 41 percent of these live in the capital city of Reykjavik. The annual rate of population increase has averaged about two percent for the past few years.

Population shifts in recent decades have been great. Until the end of the Second World War there were more Icelandic people occupied in agriculture than in any other line of activity; those employed by the fisheries being in second place. Since 1945, however, industry (including building construction) has taken first place followed by agriculture and fisheries. It is important to observe, nevertheless, that fish and fish products comprise 95 percent of the export market of the country.

Natural Resources

The natural resources of Iceland are limited, but those used chiefly by the people and which have played the most important part of their lives are the grass vegetation and the fishing grounds around the coast. There is no coal to be found in the country but small deposits of lignite exist. Peat is found in several places. Sand rich in chalk is found in the sea-bed off the southwest coast and is used for the manufacture of cement.

Hydroelectric potential is, comparatively, very great in Iceland. The technically harnessible potential is estimated at 31,000,000 megawatt hours a year under adverse hydrologic conditions and at 35,000,000 megawatt hours under average conditions. Of this total potential, at least 22,000,000 megawatt hours is expected to be economically exploitable. This potential compares with 600,000 megawatt hours of hydro generation in 1962.

~~Subterranean~~ Geothermal heat is another important source of energy in Iceland. It occurs in about 250 so-called low-temperature thermal areas (characterized by water with a temperature of up to 100 degrees centigrade) and 14 high temperature areas (characterized by natural steam ~~holes~~). Two basically different forms of geothermal heat occurrence should be distinguished: (1) recurrent form, which is comparable to hydro resources, consisting of the natural dissipation of heat to the surface in the thermal areas; and (2) non-recurrent form, analogous to [illegible] ~~comparable to an oil reservoir~~, consisting of the heat content of the hot bedrock of these areas. The natural heat dissipation of all thermal areas has been very roughly estimated at one million kilocalories per second and the bedrock heat content at between 10^7 and 10^8 Tcal (10^9 kilocalories) of which between one and ten percent is recoverable, depending on bedrock permeability, method of exploitation, and other factors. From the utilization standpoint the non-recurrent heat content of the bedrock is by far the most important form of geothermal energy so that the geothermal resources may roughly be characterized as exhaustible heat mines with a recoverable heat equivalent to several hundred million tons of oil. The gross production of geothermal heat used in the country in 1962 was equivalent to the heat content of approximately 75,000 tons of oil.

In recent years subterranean heat has been used by greenhouses and nursery farms and the use is increasing. For many years hot water from the ground has been used for the heating of houses and other buildings, as well as for the supply of hot water. Reykjavik is about 55 percent heated in this way and municipal plans call for the extension of this service to all sections of the city.

Active consideration is now being given to the feasibility of establishing a geothermal power plant for the production of electricity. In this connection several drillings have been made to assure ample initial supplies of steam.

Climatic Conditions

For Reykjavik -- the electrical load center of Iceland -- temperature, weather, and precipitation statistics are given as follows:

Annual mean temperature	5.0°C
January mean temperature	- 0.4°C
July mean temperature	11.2°C
Average annual hours of bright sunshine	1249
Average hours of bright sunshine in December	8
Average hours of bright sunshine in June	189
Annual mean precipitation	805 mm
October mean precipitation	97 mm
June mean precipitation	41 mm

Industries

The industries of Iceland based on local raw material are: various types of fish freezing and processing plants, butter and cheese factories, milk processing plants, woollen mills, tanneries, and canning factories. In the large industry class are a fertilizer plant with a capacity of 24,000 tons of ammonium nitrate per annum and a cement factory having a nominal annual capacity of 75,000 tons.

Industry based on manufacture from foreign raw materials or articles partly manufactured in other countries is of increasing importance in Iceland. Articles included in this class are: hemp and yarns, fishing lines, snoods, cod-nets, floats, barrels (wooden and steel), boxes, tins, electric stoves, paints, acetylene gas, seaman's clothes, work clothes, shirts, shoes, gloves, handbags, caps, knitted garments, soap, soap powders, shoe polish, candles, hair lotions, beauty aids, margarine, biscuits, jam, baking powder, chicory, chocolate, boiled sweets, confectionary, coffee, beer, and mineral waters.

The possibility of establishing a 30,000-ton per year aluminum smelting plant in the country is being actively considered. Such a plant would be supplied by electricity from a new hydroelectric development. To meet this requirement and those of the southwest and northern areas of the country, the Burfell Project on the river Thjorsa with a capacity of 210 megawatts, with possible enlargement when adequate storage is provided upstream, is also currently under active consideration.

Chapter III

THE ELECTRIC SUPPLY INDUSTRY IN ICELAND

Degree of Electrification

It is worthy of special note that Iceland is one of the most completely electrified countries in the world. At the end of 1962, when the population was approximately 183,000, it is estimated that 172,000 people, or 94 percent, had the benefit of electric service; 91 percent of the population having service were served by public utilities. The percentage of the total population having electric service has increased from about 80 percent at the beginning of the last decade. It is expected that the percentage will continue to increase as rural electrification is extended.

Exhibit 1 gives an indication of the areas that are now inhabited and the portion of these that are furnished with electric service. It is to be observed that this map does not show all of the electrified portion of the country because it includes only those areas supplied by public utilities, State and Municipal. There are in addition many farms, schools and industries scattered throughout the country outside the service areas that have their own private power plants. If it were feasible to include these on the map, a more complete picture of the degree of electrification in the country would be obtained.

Segregation of the Country for Power Development Studies

To facilitate power development studies, the country has been divided into the following areas as indicated on Exhibit 1, and subsequent maps:

SW - Southwest

NW - Northwest

N - North

E - East

These areas consist of the following counties:

SW	NW
Gullbringusysla	Dalasysla
Kjosarsysla	A-Bardastrandasysla
Borgarfjardarsysla	V-Bardastrandasysla
Myrasysla	V-Isafjardarsysla
Snaefellsnesog Hnappadalss	N-Isafjardarsysla
V-Skaftafellssysla	Strandasysla
Rangarvallasysla	
Arnessysla	
Vestmannaeyjar	

N	E
V-Hunavatnssysla	N-Mulasysla
A-Hunavatnssysla	S-Mulasysla
Skagafjardarsysla	A-Skaftafellssysla
Eyjafjardarsysla	
S-Thingeyjarsysla	
N-Thingeyjarsysla	

Total 24 Counties

Electrical Development in the SW-Area

While electrical statistics go back to 1904, the production of electricity was extremely small until 1920 when the first two units of the 3.2 megawatt Ellidaar hydroelectric plant were placed into operation on a small river about five kilometers from the center of Reykjavik. The next development was on the River Sog about 50 kilometers east of the capital, where 8.8 megawatts of generating plant was installed in 1937 at Ljosafoss; 5.8 megawatts were added at Ljosafoss during the war period. In 1948 a steam power reserve plant, designed to burn heavy fuel oil, of 7.5 megawatts was installed near the Ellidaar hydro plant. A second hydroelectric power plant with a capacity of 31.0 megawatts was completed in 1953 on the Sog at Irafoss. In 1960 a third hydroelectric station, Steingrímsstöð, having a capacity of 26.4 megawatts was also completed on the same river. An additional 15.5-megawatt generating unit, scheduled for completion in December 1963, is now being added at Irafoss power station.

Other plants were erected in the SW area in recent years. They included the 3.5-megawatt hydro plant (Andakill) located about 50 kilometers north of Reykjavik, which was completed in 1947, and a 7.5 megawatt diesel plant at the NATO base, about 50 kilometers west of the capital. Several smaller diesel plants were installed through the years to serve local loads, and later interconnected with the main electrical system. Notable among these was a 3.9 megawatt plant on the Westmann Islands which is now connected to the mainland by a 33 kv submarine cable.

The total installed capacity of the electric utilities and the NATO base in the SW area (including the unit to be commissioned in December 1963) is 116.0 megawatts. In addition to this there is an aggregate of

7.3 megawatts in small privately owned power plants furnishing power or back-up service for schools, farms, and industries.

Electrical Development in Other Areas

Up until 1937 the power supply in the NW area was mostly from small diesel sets. In that year a 0.6 megawatt hydro plant was erected, then extended in 1946. In 1958 a 2.4 megawatt hydroelectric plant was completed and some of the generating stations were interconnected.

The N area was largely without power until 1922 when a small hydro plant was erected. In 1939 the first hydro plant on the River Laxa, with a capacity of 4.6 megawatts went into operation. A new 8.0 megawatt hydroelectric plant on the Laxa was completed in 1953. Several small plants have been added since that time.

Electricity supply in the E area dates back to 1913 and between that time and 1958 several small hydro and diesel plants were erected. In 1958 a 2.8-megawatt hydro plant was completed. Since that time some interconnecting transmission lines have been built.

Privately Owned Power Plants

As previously indicated, there are numerous small power plants spread throughout the inhabited areas of the country serving schools, farms and industries. These plants produce electricity from hydro, diesel and, in a few instances, fuel-produced steam. It is reasonable to assume that, as the availability of utility service is extended further, the production of the non-hydro plants now in regular operation will be replaced by production from the central systems. It may also be assumed that some of the hydro plants will also be shut down because of high operating costs as they approach the end of their useful lives.

A summary of the number, size and type of the privately owned plants, not including the NATO plant, as of January 1, 1963 is given as follows:

	HYDRO		THERMAL	
Area	Number of Plants	Total Installation-Name Plate Rating - Kw	Number of Plants	Total - Kw
SW	133	1,421	159	2,439
NW	44	622	180	2,416
N	115	1,415	136	5,211
E	59	545	83	811
Totals	351	4,003	558	10,877

	RESERVE		TOTAL	
Area	Number of Plants	Kw	Number of Plants	Kw
SW	51	3,398	343	7,258
NW	3	46	227	3,084
N	13	515	264	7,141
E	7	195	149	1,551
Totals	74	4,154	983	19,034

Installed Generating Capacity

The total installed name plate generating capacity in Iceland at the end of 1963 will be 170.5 megawatts. This amount consists of 144.0 megawatts installed by the public utilities and an aggregate of 26.5 mega-watt capacity in small plants scattered throughout the country; 11.7

megawatts of the latter is interconnected with utility systems and maintained almost entirely for back-up service. The electrical generating capacity installed in the country is summarized, in megawatts, as follows:

	SW	NW	N	E	Total
Hydro (Utility)	95.0 1/	4.5	17.7	3.2	120.4
(Private)	1.4	.6	1.4	.6	4.0
Total Hydro	96.4	5.1	19.1	3.8	124.4
Thermal (Utility)	13.5	2.2	4.4	3.5	23.6
(Private)	13.3 2/	2.5	5.7	1.0	22.5
Total Thermal	26.8	4.7	10.1	4.5	46.1
Total Capacity	123.2	9.8	29.2	8.3	170.5

Production of Electricity

While 27 percent of the total installed capacity consists of thermal plant, approximately 97 percent of the electrical energy produced in the country comes from hydro plants. The steam and diesel plants are used mostly to provide back-up service. In several small isolated locations, however, diesel plants are the only source of electricity supply and in such places the entire electricity requirements are met from these plants.

1/ Includes 15.5 megawatts of new capacity at Irafoss power station scheduled for operation in December 1963.

2/ Includes the 7.5-megawatt diesel power station at the NATO Base.

Energy production by the utilities in the four areas of the country for the past decade is given as follows:

GWH Production [1/]

Year	SW	NW	N	E	Total
1953	176	6	43	4	229
1954	283	6	46	4	339
1955	328	6	51	5	390
1956	350	7	55	5	417
1957	355	7	59	6	427
1958	365	9	64	8	446
1959	395	12	67	10	484
1960	443	15	68	10	536
1961	484	17	75	12	588
1962	492 [2/]	18	83	13	606 [2/]

Electricity Rates

The cost of electric service to the consumer is low. During past years, and at the present time, rates have been such as to induce the maximum use of electricity by all classes of consumers served. The average rates for electricity supplied by all the utilities in Iceland combined, for the year 1961, are as given below:

1/ To obtain the total energy production in Iceland the output of the privately owned plants would have to be added. This was estimated to be 15 GWH in 1962, and would be about the same throughout the decade.

2/ Would have been higher but for a break-down at the fertilizer factory.

Class of Consumer	Average Rate Aurar/Kwh	Average Rate U.S. Mills/Kwh[1/]
Domestic	90.0	21.0
Space Heating	22.6	5.3
Commercial	156.0	36.3
Handicrafts	146.3	34.1
Industrial	54.2	12.6
Public Lighting	82.5	19.2
Heavy Industry	25.5	5.9
Miscellaneous	45.2	10.5

Alternative Costs

Alternative to the purchase of electricity from a public utility, an industrial consumer would normally have to produce it from imported fuel. The cost of this fuel is such that there is considerable savings -- under present tariffs -- from purchased electricity. The cost of fuel oil (Bunker C) delivered at seaports in Iceland is currently kr 1063 ($24.72) per metric ton and of diesel oil kr 1.50 ($0.035) per liter. Light fuel oil, used for heating, costs kr 1.55 ($0.036) per liter.

Future Sources of Power Supply

In the SW area, the Municipality of Reykjavik is about to order a 11.5 megawatt steam turbo-electric set to use the full output of a boiler that has been used occasionally for boosting the temperature of the hot water supply to the city. This capacity, together with the existing 7.5 megawatt plant, will be used as reserve. An additional installation which

1/ Converted at the current exchange rate of $1.00 = 43 kr.

will achieve the full development of the Sog potential is a hydro unit (7.0 megawatts) which is being considered for installation at the Ljosafoss Power Plant in the future.

With the existence of great hydroelectric potential and a substantial amount of geothermal energy that can be harnessed, the future electricity requirements ultimately can be met completely by internal sources. Aided by the interconnection of systems, continued load growth and greater distances of transmission, now economically feasible, larger developments can, and are, being considered.

Studies have been made for a geothermal electricity generating plant of 16.0 megawatt capacity and, alternatively, one of 32.0 megawatt capacity. It would be located in the vicinity of Hveragerdi, not far from the Sog plants and about 50 kilometers from Reykjavik.

Engineering studies have also been made of the Burfell Hydroelectric Project on the Thjorsa, the location of which is about 110 kilometers from Reykjavik and 220 kilometers from Akureyri. Plans for this development call for initial and intermediate capacities of 105 megawatts and 210 megawatts, respectively. Units are to be rated at 35 megawatts each. Storage upstream, if built in the future, would permit a larger ultimate installation.

The Vordufell Pumped-Storage Project, to provide peaking and reserve capacity, has also been appraised. This project would be located about 65 kilometers from Reykjavik on the River Hvita, between the Sog plants and the Burfell site. Generating capacities up to 60 megawatts, have been considered in connection with small system reserves. The potential of the site is well over one million kilowatts.

There are numerous sites for hydroelectric development throughout the country. The cost of local development compared with interconnection with other areas will be carefully studied as the loads increase. In connection with the Burfell Project, it is proposed to interconnect the two largest electrical systems in the country, namely, those of the SW and N areas.

Chapter IV

GENERAL USE OF ELECTRICITY

Consumption Per Capita

The consumption of electricity per capita in Iceland has been steadily increasing and has more than doubled in the last decade. This is shown graphically in Exhibit 2. The calculated electrical consumption per person for 1962 was 2850 kilowatt hours. This would have been higher but for the curtailed consumption of the largest electrical consumer -- the fertilizer factory -- resulting from a breakdown. It is estimated that the present annual rate of consumption per capita is approximately 3000 kilowatt hours. Iceland is, therefore, among the European countries leading in the consumption of electrical energy in proportion to the population, and indeed is among the top group for the entire world.

One noticeable factor that has had an important bearing on the increase in the consumption of electricity per capita has been a steady and substantial migration of people from the rural to the urban areas since the turn of the century. This has been, in effect, a movement of population from districts without electricity supply to districts having electric service. Statistics show that in the year 1900, 20 percent of the people in the country lived in towns and villages with over 300 inhabitants, and 80 percent lived in rural districts. In 1960, however, the situation was completely reversed, with 80 percent of the population living in cities, towns, and villages having a population of over 300.

Cooking and Heating

Cooking by electricity has been widely adopted in all areas where electric service is available. It is generally competitive with fuel so that people of all classes use electric stoves for the cooking of food. In fact, all types of domestic electric appliances are widely used. Many of these are manufactured in the country.

Space and water heating by electricity is used to a considerable extent, except in a large portion of the city of Reykjavik and a few other areas where natural hot water service is available. Special rates are applicable to energy used for space heating and these are sufficiently low to encourage this type of use. The rates for water heating are also competitive. Temperatures are such as to establish a certain demand for space heating throughout the year.

Refrigeration

Domestic refrigeration is widely used and its use is only limited by the cost of refrigerators, which not all families can yet afford. Deep freeze units are also used to some extent, particularly where it is impossible or undesirable to purchase food frequently.

Large scale refrigeration and the manufacture of ice for the fishing industry has increased greatly since World War II. This has resulted from a change in the overseas market for fish in that there has been a large increase in the demand for frozen fish products. The extent of this change is indicated by the increase in the amount of fish frozen each year. This approximated 57,000 tons in 1950, but exceeded 200,000 tons in 1960. Refrigeration is also used to an increasing extent for freezing herring for bait which is held in cold storage for sale to the fishing boat operators.

Refrigeration is now extensively used for the preservation of meat; chiefly lamb and mutton. It is customary to slaughter lambs and sheep in large numbers at the end of the grazing season. This meat is frozen and held in cold storage for use throughout the following twelve months. An indication of the increase in refrigeration requirements for this purpose may be had from statistics of the number of lambs and sheep killed. The total in 1935 was 373,900 which increased to 822,400 in 1961. Some of this meat is frozen and held in cold storage for export. In 1962, over 3000 tons of frozen lamb and mutton were shipped overseas.

Industrial Use

There are an increasing number of industries being established, all of which use electric power and energy to a greater or lesser extent. The processing of dairy products is steadily increasing to meet the home consumption of dairy products. In 1935, for example, five dairies operated in the country and processed a total of about 11,000 tons of milk. By 1961, the number of dairies had increased to fourteen and in that year they processed a total of 82,000 tons of milk.

The number and output of herring factories has also increased. A measure of this increase may be observed from the production figures of the herring factories as shown below:

	Herring Oil	Herring Meal
1950	4,300 Tons	5,000 Tons
1960	18,200 Tons	19,500 Tons

Similar indications of growth are reflected by a sustained increase in the electric consumption of a variety of small industries.

The use of electricity by the two largest established industries, the fertilizer factory and the cement plant, will be dealt with in a subsequent section of this report, under specific use.

Rural Use

The State has done a commendable job in extending electric service in the rural areas. In 1952, when the State embarked on a progressive Rural Electrification Program, there were 1276 electrified farms in the country. At the end of 1964, it is estimated that electricity will be available to 4090 farms. There remain only 1910, or 32 percent of the farms without the benefit of electricity. Extension of Rural Electrification systems is still continuing.

One use of electricity on the farms that is receiving wider application, of late, is the inside drying of hay by electrically driven fans. Because of frequent rain and limited sunshine a certain amount of hay can not always be completely dried outside during the summer. Fans have been successful in saving hay that would otherwise spoil, and this use of electricity is expected to increase.

Both the number of electrified farms and electrical load per farm are expected to increase.

Illumination

In Reykajavik the longest day of the year -- sunrise to sunset -- is approximately 20 hours and the shortest about four hours. The variation in the northern areas is, of course, greater. The load factor of the lighting demands is therefore very high in winter and very low in summer.

The people of Iceland display a desire for the generous use of good illumination and it is a reasonable assumption that the present rate of increase in energy use for this purpose will continue.

Chapter V

ELECTRIC SUPPLY AGENCIES

In the generation and transmission sector of the electric utility supply industry there are three classes of owners: Municipal, State, and Joint (state and municipal). Of the generating plant of the utilities, 17 percent is municipally owned, 71 percent is jointly owned, and 12 percent is state owned.

In the distribution and retail sector there are only two types of ownership, Municipal and State. Municipal systems supply 81 percent of the population served with electricity and State systems supply 19 percent.

Municipal Electric Utilities

There are 22 Municipal Electric Utilities in the country. Most of these are located in the SW area, including Reykjavik and other towns in the vicinity of the capital city. The location of these utilities is shown on Exhibit 3.

The areas are located as follows:

SW	NW
Reykjavik	Patreksfjordur
Hafnarfjordur	Isafjordur
Vatnsleysa	
Njardvikur	
Keflavik	
Gardur	

SW	NW
Sandgerdi	
Grindavik	
Eyrarbakki	
Stokkseyri	
Selfoss	
Hveragerdi	
Vestmannaeyjar	
Akranes	
Borgarnes	

N	E
Saudarkrokur	Reydarfjordur
Siglufjordur	
Akureyri	
Husavik	

The State Electricity Authority

The State Electricity Authority (SEA) grew out of the state electrical inspection department which was established in 1933. In 1946 the Althing (parliament) passed the Electricity Act which made the State chiefly responsible for further electrification. The main function of SEA has been the progressive establishment of electric service in areas where such did not exist. SEA has further extended its activities and now performs such additional functions as geothermal research, power economy, standardization, accumulation of hydrologic and topographic data, and system power resources planning. SEA has been responsible for the large percentage of rural areas and smaller villages having the benefit of electric service today; and the extension of service to such areas is continuing. SEA has made available power in wholesale amounts to municipalities and large industrial consumers, in addition to constructing transmission and distribution systems in areas not having other utility service.

Exhibit 3 also shows the location of State electric supply systems. On December 1, 1962 these systems supplied the following:

		Number of People Served		
Area	Number of Districts	In Towns and Villages	In Rural Areas	Total
SW	8	3,884	6,400	10,284
NW	5	3,658	600	4,258
N	7	5,704	4,400	10,104
E	5	6,010	600	6,610
Total	25	19,256	12,000	31,256

An illustration of SEA service was the placing in operation in 1962 of a 33 kv submarine cable connecting the municipal utility of the Westmann Islands with the SW interconnected system. This connection will enable the local municipality to almost completely eliminate production from diesel sets when the supply line from the Sog plants is strengthened; and to lower its rates so that it will be profitable for private operators on the Westmann Islands to shut down their diesel plants.

Chapter VI

SPECIFIC USE OF ELECTRICITY

In this study, the consumers of electricity have been divided into two main classes, the ordinary consumers of all the utilities and the three largest individual power consumers, which are: (1) NATO Base, (2) the fertilizer factory, and (3) the cement factory. Each of the three large power consumers is examined on the basis of its individual characteristics in respect to the present and likely future power and energy requirements.

Energy Used by the Ordinary Electricity Consumers

A classification of the various uses of electricity and the amount of energy used by each class of ordinary consumers can be observed from the following analysis of energy sold by all the utilities in 1961:

Class of Use	Thousands of Kwh	Percent of Total
Commercial Lighting	22,350	7.0
Domestic	105,979	33.1
Small Power	11,898	3.7
Large Power	75,204	23.5
Space Heating (Day)	40,843	12.8
Space Heating (Night)	33,492	10.5
Commercial Catering	3,844	1.2
Bakeries (Night)	3,599	1.1
Street Lighting	9,094	2.9
Hay Drying	1,599	0.5
Other	11,987	3.7
	319,889	100.0

The above classification was made according to tariffs. Night service is supplied in some instances at special rates for the purpose of increasing the utilization of available off-peak energy, which has proved to be very successful. A large portion of space heating energy is supplied to residential consumers and this combined with domestic use aggregates about 50 percent of the above total use. This furnishes a very stable and substantial component of the total electric load.

The amount of electrical energy used for space heating in the city of Reykjavik will be reduced somewhat as a result of a program for increasing the supply and extending the distribution facilities of natural hot water for heating and ordinary use. In 1963 about 55 percent of the population of the city have piped-in hot water supply and it is intended to extend this service to within reach of 90 percent to 95 percent of the population in the next four years. In 1961, 32 percent of the total electrical energy used for space heating was consumed in the city of Reykjavik. This amounted to 13.573 GWH under the day tariff and 10.503 GWH at the more favorable night rate.

It has been the experience to date that, with change over to purchased hot water, practically all of the day electric space heating is eliminated by the individual consumers, while about two out of three retain electric space heating at night. On the other hand, the number of electrically driven pumps and the electricity for their operation will be increased greatly with the extension of hot water service. All of these factors have been taken into consideration in forecasting the future electricity requirements for space heating.

Power and Energy Used by the NATO Base

The NATO Base at Keflavik has its own central diesel generating plant with a capacity of 7.5 megawatts and numerous smaller plants scattered about the base for back-up service. These smaller plants have an aggregate capacity of 5.0 megawatts. In order to minimize the use of imported diesel oil and use lower cost electricity that could be provided by the new 66 kv line from Reykjavik to Keflavik, a 5.8-megawatt frequency changer (fifty to sixty cycles) was installed during 1960. At the present time (November 1963) all of the power requirements of the base are being met from the system, except at the time of the heaviest peaks when the diesel plant is started up in order to hold the load on the frequency changer within its rated capacity.

Plans call for the addition of a second frequency changer (also of 5.8-megawatt capacity) to take care of the future load. The present maximum demand and energy purchases by the NATO base per annum from the system is 5.8 megawatts and 40 million kilowatt hours, respectively. Estimates of future power and energy requirements of, and purchases by the base, have been made in accordance with data received from NATO engineers and incorporated in the forecasts in this Report.

Electricity Supply to the Fertilizer Factory

The largest single consumer of electric power and energy is a fertilizer factory located just outside of Reykjavik. It has a maximum demand of 19 megawatts and has consumed the following amounts of energy in recent years:

1960 - 133 GWH
1961 - 142 GWH
1962 - 125 GWH

In 1963, the fertilizer factory is using energy at the annual rate of approximately 140 GWH, which is almost one-quarter of the energy presently used in the country.

The capacity of the fertilizer factory is 24,000 tons of ammonium nitrate per year. The maximum produced by the plant in any one year has been 23,000 tons. The present demand in the country for fertilizer is approximately 28,000 tons per year, which has been increasing at rates between 7.5 percent and 10 percent per year. It is estimated that by 1968 there will be an internal market of between 36,000 and 41,000 tons, sufficient to warrant a 100 percent increase in production facilities which, if added, would be at the location of the existing fertilizer factory.

About 87 percent of the electrical energy now used by the fertilizer factory is for the production of hydrogen by the electrolysis of water. The factory has a primary power contract for 3.1 megawatts; the balance of the power is secondary. Since the fertilizer factory commenced operation in 1953, it has curtailed operation during the heavy load hours of the electric system to reduce demand on the system.

While no definite plans for the likely future fertilizer plant have yet been made, it has been assumed, on the basis of information supplied by the plant management, that the new plant will employ a different process and that each additional plant of 24,000 tons capacity would use only a continuous demand of 3.1 megawatts. The existing plant will, of course, continue to use secondary energy, to the extent available.

In the forecast of the power requirements of the fertilizer manufacturing industry, it has been assumed that a new production unit would be established in 1968 and another in 1976. It was also assumed that the annual amount of primary energy -- or energy to which the fertilizer plant would be entitled under the present primary contract -- would be 27 million kilowatt hours. This amount would be doubled in 1968 and trebled in 1976 when new units would be added. In addition to this, up to 149 GWH per year of secondary energy might be used, as and when surplus is available from hydro sources.

Power and Energy Requirements of the Cement Factory

The cement factory at Akranes, which has a designated capacity of 75,000 tons[1] per year is the only cement plant in Iceland and can more than meet the requirements of the country. In fact, over 18,000 tons were exported in 1962. The power and energy requirements of this factory at the present time is 2.0 megawatts and 12 million kilowatt hours per year, respectively. It is expected that this load will not increase in the immediate future but it will, of course, be necessary to increase the production of cement as the local demand increases. For the purpose of this study, in respect of estimates of future power and energy requirements, the cement factory was merged with that of the ordinary electricity consumers and was assumed to increase at the same rate as the power consumers in that group.

1) The actual capacity, however, is at least 100 000 tons a year.

Chapter VII

EXISTING ELECTRIC SYSTEMS

There are several electric systems in Iceland each comprised of two or more power stations interconnected and operated as a single system. On the other hand, many small towns and villages are supplied with electricity by an isolated plant with local distribution facilities. The number and location of these groups and of isolated utilities are shown on Exhibit 4. As indicated on Exhibit 4, some of the power stations and transmission lines are jointly State and Municipally owned. This situation exists on the so called Sog system in the SW area, where the principal power stations and transmission lines are owned partly by the State and partly by Municipalities. The same is true of the Laxa-Akureyri system in the Northern area.

The total installed generating capacity of the electric systems is shown on Exhibit 4 as 151.5 MW. To this should be added the aggregate capacity of the privately owned power stations (19.0 MW) to arrive at the total installed capacity in the country of 170.5 MW at the end of 1963.

Chapter VIII

POSSIBLE FUTURE INTERCONNECTION

Exhibit 5 shows possible future interconnections within the four areas and between three of the four areas. Such interconnections in the future, along with larger scale hydroelectric development, will minimize the use of imported fuel for power production purposes, permit larger developments at lower cost per kilowatt of capacity and make possible joint operation of utilities from which advantage can be taken of diversity of both supply and demand. It will also permit reserve capacities to be reduced to a minimum.

From studies that have been made previously there appear to be limited possibilities of constructing economical hydropower plants of suitable capacity in area E; therefore it seems likely that areas N and E will be interconnected eventually. As this problem will require further careful study, it was assumed for the purpose of the forecast that only the SW-N intertie would come into existence in the near future. Interconnection of the NW area with other areas was not considered in this study. The loads in the NW area are small and scattered and interconnection with other areas would be unduly expensive in the foreseeable future.

Chapter IX

FORECAST OF FUTURE POWER AND ENERGY REQUIREMENTS

Based on the analyses of statistics relative to electricity used by the various classes of consumers in the different areas of Iceland during the past ten years and, taking into consideration all governing factors, twenty-year forecasts of power and energy production requirements are made for the SW, N, NW, and E areas as well as for a SW-N integrated system.

There are three methods normally used in making power market forecasts, namely: comparative utilization, specific load estimates and trend analysis. Frequently all of these methods are employed but for these forecasts the trend analysis, applied to the various classes of electrical consumers, was used for the SW, N, and E areas and the comparative utilization method for the NW area.

The trend analysis method of forecasting was generally adopted because there are good records for past years of energy consumption by various classes of consumers; established under the favorable conditions of good electric service at reasonable cost to the consumer. With the exception of the NW area the forecasts were made by projecting into the future established past trends for the various classes of use with suitable correction for factors that would alter the trends. Upon these forecasts were superimposed the specific power and energy estimates for the very large consumers, namely: (1) NATO base, (2) the fertilizer factory, and (3) the proposed aluminium plant.

In the NW area the comparative utilization method was used because there are indications that the population in this area will not increase and that industry, in the foreseeable future, will be confined to the processing and preservation of fish.

Southwest Area

The population of the SW area in December 1962 was 130,286 or 71.0 percent of that of the entire country. The largest concentration of electricity demand on the present interconnected system in the SW area is the city of Reykjavik. This situation will probably continue to exist. It is also likely that the class of electrical consumer that will continue to predominate the ordinary demand for electricity in this area, as well as the other areas of the country, will be the domestic users. This class of consumer has characteristic stability and it is reasonable to assume that the aggregate electrical requirements of the domestic consumers will, in the future, follow the same trend as they have in the past.

Statistics of electricity consumption by the various classes of consumers in the SW area for the ten-year period 1952-1961, inclusive, are given in Table I at the end of this Report. From an analysis of these figures, it has been determined that, while the components of the total load have shown some variations in trend, the combined energy requirements of the area have indicated a fairly constant rate of increase. The ten-year annual average increase in energy consumed by the ordinary primary consumers, was 7.2 percent. The only secondary power consumer, up to the present time, is the fertilizer factory. Estimates of the primary component of this load were made and then merged with those for the ordinary consumers of electricity.

The increase in domestic consumption for the area average 6.7 percent per annum in the ten-year period, parallel with a local average population increase of 2.9 percent. It is assumed that this rate will continue throughout the twenty-year period of the forecast.

While space heating increased substantially in the ten-year period, conditions have altered that will materially effect the electricity requirements for space heating during the next few years. Electric space heating now used in Reykjavik is likely to be greatly reduced during the next four or five years as the municipal hot water supply system is extended. It is within the bounds of possibility, that towns west of Reykjavik may also obtain natural hot water supply within the period of this forecast. In other parts of the SW area it was assumed that electricity consumption for space heating will continue to increase. All of these factors have been taken into consideration in the forecast of likely future requirements.

Use of electricity by commercial consumers increased, on the average over the ten-year period, at the rate of 11.2 percent. It was assumed for the purpose of this forecast that this rate of increase would continue.

The average annual increase in electrical energy used for public lighting has been about 12.5 percent; it was assumed also, that the average future rate of increase would be at the same rate.

The average rate of increase in electrical energy purchased, during the past ten years, by the industrial and miscellaneous consumers in the SW area -- exclusive of the fertilizer factory, NATO, and the cement factory -- was 7.7 percent. The average, however, for the last three years of the period was approximately 7 percent. On the basis of these observations it was assumed that the future rate of increase of electricity consumption of the industrial and miscellaneous consumers would be at the annual rate of seven percent. For the purpose of the forecast, also, the cement factory was merged with the ordinary industrial consumers and the electrical consumption of this industry was also assumed to increase at a seven percent annual rate.

Regarding the small private plants still operating in the area, it was assumed that practically all of the thermal plants and half of the hydro plants would be replaced by purchased power within the period of these estimates.

Table II gives annual figures of energy production for the past ten years as well as the maximum demand and load factor for the past few years, after most of the utilities in the SW area became integrated into one electrical system. In this tabulation an attempt has been made to segregate the ordinary consumers (all consumers with the exception of NATO and the fertilizer factory) and determine the energy production, maximum coincident demand and the corresponding annual load factors for supply to these consumers for the past five years.

It will be observed that the annual load factor, in respect of the ordinary consumers is in the vicinity of 50.0 percent and for the year 1962 was calculated to be 52.0 percent. The load factor has been increasing slightly because of the substantial increase in the refrigeration load; the tariffs designed to increase night use, and the more or less continuous operation of the cement plant. It would seem, however, that further increases in load factor for power and energy supply to the ordinary consumers may not be expected for three reasons. First, there probably will not be as great an increase in refrigeration in proportion to the whole load in the next decade as there was in the last; second, the miscellaneous industries that will be established in the future will probably operate, mostly, on a single shift basis, and third, the predominating domestic consumers will continue to use electricity on much lower than 50 percent annual load factor basis.

Giving due consideration to the above characteristics of use it is estimated that the annual load factor of the system, while meeting the requirements of the ordinary consumers of electricity in the SW area, will stabilize and for the purpose of these forecasts, a value of 52.5 percent has been used.

Table III summarizes the estimates, based on the above assumptions. To the estimated power and energy production requirement of the ordinary consumers are added separately-made estimates of production for the NATO base and the fertilizer plant primary loads. Figures, taken from Table III give an indication of the forecasted power and the energy production requirements and the annual load factor of the consolidated primary load in the SW area as follows:

Year	Energy Production (GWH)	Maximum Demand (MW)	Load Factor (%)
1962	386.5	78.7	56.1
1967	515.4	103.0	57.0
1972	743.4	149.9	56.7
1977	1025.2	205.9	57.0
1982	1363.5	278.9	55.8

Northern Area

In December 1962 the N area had a population of 30,834, or 16.8 percent of that of the country and contains Akureyri, Iceland's second largest city. The energy consumption per capita in this area for 1961 approximated 2000 kilowatt hours per annum, which was about the same as in the SW area on the basis of the ordinary electricity consumers. A comparatively large amount of energy is used in the N area for space heating.

Table IV gives a ten-year record of electricity consumption in the N area, in addition to other basic data. An analysis of these figures reveals an average annual increase in electricity consumed of 7.3 percent during this period. For the latter five years of the period the average increase was 6.5 percent. The larger component of the increase has been industrial chiefly those industries associated with the processing and preservation of fish.

In the forecast for the N area it was assumed that with further interconnections between plants in the area and as more generating capacity is made available, all the small thermal plants and half of the independent hydro stations would be shut down within the twenty-year forecast period.

The average rate of increase by the domestic consumers, at 4.7 percent, was observed to be lower than in any other area and, for the forecast, it was assumed that this would increase. On the other hand, distribution facilities in some places in the area are now overtaxed by superimposed space heating load. The increase in consumption of this class of consumers, therefore, was assumed to be less in the future than it has been in the past. The commercial load and public lighting was assumed to continue at the present rate of increase while it was considered likely that the requirements of industry and of the miscellaneous consumers would be at a reduced rate.

While the whole N area is not now interconnected, it was assumed that it would be in the future and an attempt was made, therefore, to estimate the likely coincident maximum demand and project it into the future. It is observed that the calculated load factor for 1962 was 60 percent. This comparatively high value is because of the large amount of energy being used off-peak for space heating. As the domestic and industrial load grows in the face of curtailed new connections for space heating, the load factor is expected to decrease. It was assumed, therefore, that the load factor will gradually drop and stabilize in the vicinity of 53.0 percent.

A forecast of energy sales, production, maximum demand and load factor for the N area are summarized in Table V. The following extracts from this Table show the forecasted power and energy requirements at five-year intervals:

Year	Energy Production (GWH)	Maximum Demand (MW)	Load Factor (%)
1962	83.0	15.8	60.0
1967	108.0	21.4	57.5
1972	141.8	29.4	55.0
1977	187.5	40.4	53.0
1982	251.3	54.0	53.0

Northwestern Area

In the past decade, the population of the NW area has not increased; in fact, it has gone down slightly. The number of people in the area in December 1962 was 11,694, or 6.4 percent of that of the whole country. The consumption of electrical energy in the NW area, by classes of consumers, for the ten-year period (1952-1961) is given on Table VI. An analysis of these figures indicates an average annual rate of increase for the period of 13.1 percent. The comparatively high rate, in face of a decrease in population has been caused by several factors. At the beginning of the period (1952) and even until 1958, when two hydro plants went into operation, there was insufficient power available in the area. Up until this time the area refrigeration plants used direct-drive diesel engines. At the same time domestic consumers were unable to obtain the amount of electricity they would have been able to use. After completion of the hydro plants and transmission lines in 1958 there was a sudden increase in utility-supplied power and energy. In addition, the first herring processing plants were established during 1963.

It cannot be expected that the rate of increase of the past few years in the NW area will continue far into the future. In view of this situation it was assumed that at the end of twenty years the area would have the same population as at present and the energy consumption per capita would be in the vicinity of 4000 kilowatt hours per annum. This may be compared with 5000 kilowatt hours calculated from the estimates made by projections for the N area.

As in the case of the preceding forecast, it was assumed, for estimating purposes, that the power stations in the area would all be interconnected and the coincident maximum demand was estimated on this basis. It is observed that the annual load factor has been increasing with the recent increase in industrial consumption. It was assumed for this forecast, however, that the annual load factor would stabilize in the vicinity of 47.5 percent.

Based on the above assumptions, forecasts were made and the results of these are summarized on Table VII.

Extracts from Table VII shows the magnitude of the NW area load and that forecasted for the future, in five-year intervals, as follows:

Year	Energy Production (GWH)	Maximum Demand (MW)	Load Factor (%)
1962	18.0	4.5	45.7
1967	28.8	6.9	47.5
1972	40.2	9.7	47.5
1977	51.5	12.4	47.5
1982	62.8	15.1	47.5

Eastern Area

In December 1962, the population of the E area was 10,664, or 5.8 percent of the aggregate number of inhabitants of the country. The annual rate of population increase for the past five years has been 1.2 percent and if this continues for the twenty-year forecast period the area population will be approximately 13,500. The electrical consumption for the E area for the year 1961 was 830 kilowatt hours per capita.

Figures of electrical energy consumption by the various classes of consumers for the years 1952 to 1961, inclusive, are shown in Table VIII. These statistics indicate that there was an average annual increase of 12.1 percent during this period.

From 1952 up to 1958 there was insufficient power available in the E area. Many generating plants and distribution facilities were then in a more or less deteriorated condition. Until the State took over the responsibility for power supply in the area, refrigeration and herring processing plants were operated by direct-drive diesel engines and the general electricity consumption level was low. After the completion of a hydro plant in 1958, with associated transmission lines and improvements in the area distribution systems, there was a sharp increase in the consumption of electricity. Electric motors replaced most of the diesel engines in the area. The herring processing industry has grown rapidly in the E area during the last three to four years.

It seems reasonable to expect that a gradually reduced rate of increase in electricity consumption will be experienced in the future. For the purpose of this forecast a gradual reduction in the present annual rate of increase from present levels to about five percent during the latter part of the twenty-year forecast period was assumed.

Again, for the purpose of this study, estimates were made on the basis of all the electrical utilities in the area being considered as physically interconnected. Annual coincident maximum demands were thereby established and the corresponding load factors calculated. These are shown on Table VIII. A slight upward trend in the load factor is observed. It was assumed for this forecast that an increase would continue at the present trend until 45.0 percent is reached and thereafter the annual load factor would remain constant.

By the application of the above assumptions, forecasts were prepared for the E area, the results of which can be found on Table IX.

The magnitude of the likely power and energy requirements will be observed from the following extracts from Table IX for selected years at five-year intervals:

Year	Energy Production (GWH	Maximum Demand (MW)	Load Factor (%)
1962	13.0	3.9	38.0
1967	23.2	6.1	43.0
1972	36.5	9.3	45.0
1977	55.4	14.0	45.0
1982	76.7	19.4	45.0

If the above 1982 aggregate energy sales in the eastern area are realized, along with a continuation of the present rate of population increase in the interim period, the annual energy consumption per capita will then approximate 4000 kilowatt hours.

Chapter X

FORECAST FOR THE SW-N INTEGRATED SYSTEM

Associated with a large scale power development, such as the Burfell Project, might be an intertie between the SW and N electric systems. This would permit the new project in the SW area to replace thermal generation in both areas as soon as the first stage is completed. This new capacity would also provide for the ever increasing demands for power and energy in the combined areas.

The forecast of the integrated system is obtained by combining the previous forecasts for the SW and N areas. This amounts to the addition of the energy production requirements of the two systems. It also necessitates combining the maximum demand of the SW system with the coincident demand of the N system.

It has been observed that the annual maximum demand of the SW system occurs between the 9th and the 25th of December. In four of the five past years the maximum was established at 11:30 a.m. and in one of these years at 7:00 p.m. This indicates that presently -- and probably in the future -- cooking of the main daily meal will govern the time of the maximum demand for electricity within this narrow fifteen-day period of December. It is customary in Iceland to have the main daily meal at noon, except in the evening of the day before Christmas, at which time the annual maximum demand may occur.

Studies of the electrical demand on the system serving Akureyri and surrounding areas also indicate that the maximum demand for the year is normally established during the same period of December as for SW system. Studies have also revealed that an annual maximum demand in the N area may occur either at 11:30 a.m. or between 6:00 p.m. and 7:00 p.m.

It may be concluded that there is only a very slight diversity between the annual maximum demand of the SW and the N systems and for the purposes of this forecast it was assumed that the resultant reduction in the amalgamated demand may not be any more than sufficient to offset the superimposed transformation and transmission losses in respect of power produced in the SW area and used in the N area. Based on this assumption, production for the integrated system maximum demand was arrived at by the direct addition of the maximum demands of the individual systems.

As indicated earlier, active consideration is being given to the establishment of an aluminium reduction plant in Iceland. It is estimated that the production of power and energy at Burfell to supply an aluminium plant with one potline would require 55 megawatts and 470 GWH per year, respectively.

Based on the above assumptions the combined power and energy requirements of the SW-N integrated system (without and with the aluminium plant) are determined on Table X.

Figures of the forecasted power and energy production of the SW-N integrated system have been extracted from Table X for selected years, spaced at five-year intervals, and are reproduced as follows:

Estimated Production of the SW-N Integrated System

Year	Energy (GWH)		Maximum Demand (MW)	
	Production	Increment	Production	Increment
1962	469.5		94.5	
1967	623.4	153.9	124.4	29.9
1972	885.2	261.8	179.3	54.9
1977	1212.7	327.5	246.3	67.0
1982	1614.8	402.1	332.9	86.6

If the aluminium plant is constructed and ready for operation at the beginning of 1968, the energy production shown above will have to be increased by 470 GWH and the maximum demand by 55.0 megawatts for 1972, 1977, and 1982, respectively.

Chapter XI

SUMMARY AND CONCLUSIONS

A summary of the maximum power production in megawatts for the four areas of Iceland, and the corresponding total for 1962 as well as for selected subsequent years forecast in this study is as follows:

	1962	1967	1968	1972	1977	1982
SW Area (MW)	78.7	103.0	113.3	149.9	205.9	278.9
N Area (MW)	15.8	21.4	22.8	29.4	40.4	54.0
NW Area (MW)	4.5	6.9	7.4	9.7	12.4	15.1
E Area (MW)	3.9	6.1	6.6	9.3	14.0	19.4
Subtotals (MW)	102.9	137.4	150.1	198.3	272.7	367.4
For Proposed Aluminum Plant (MW)	-	-	55.0	55.0	55.0	55.0
Grand Total (MW)	102.9	137.4	205.1	253.3	327.7	422.4

The above amounts are the estimated coincident production maximum demands to supply the primary consumers. An additional load, up to the equivalent of 17.0 MW production, can be used by the existing fertilizer factory when surplus hydro capacity is available.

A summary for energy similar to the one given above for power is as follows:

	1962	1967	1968	1972	1977	1982
SW Area (GWH)	386.5	515.4	555.9	743.4	1025.2	1363.5
N Area (GWH)	83.0	108.0	113.8	141.8	187.5	251.3
NW Area (GWH)	18.0	28.8	31.0	40.2	51.5	62.8
E Area (GWH)	13.0	23.2	25.5	36.5	55.4	76.7
Subtotals (GWH)	500.5	675.4	726.2	961.9	1319.6	1754.3
For Proposed Aluminium Plant (GWH)	-	-	470.0	470.0	470.0	470.0
Grand Totals (GWH)	500.5	675.4	1196.2	1431.9	1789.6	2224.3

Here again, the above figures are for primary load production. The fertilizer factory can use, in addition to that included in these figures, up to the production equivalent of 17.0 megawatts at 100 percent load factor, or 149.0 GWH per annum.

It must be pointed out that for the NW and the E areas, the demand figures cannot be used as given above for the determination of the plant capacity required to meet the future demands in these areas because many of the power stations lack interconnection. While this condition prevails, the aggregate plant capacity in these areas will be considerably in excess of the total coincident maximum demand. Energy production in the NW and E areas, however, should be approximately as given in the tabulation immediately above, if the forecasts prove to be reasonably accurate.

With regard to the proposed SW-N integrated system, the combined demand forecast can be used directly to determine the additional plant capacity required for these amalgamated areas.

If a new major hydro project is begun without delay, it may take until the end of 1967 to complete. The power supply and demand position at that time may be estimated as follows:

	SW	N	Total
Hydro capacity (MW)	95.0	17.7	112.7
Estimated 1967 demand (MW)			124.4
Estimated 1967 thermal peak production			11.7 MW

At the end of 1967, the firm capacity of the integrated system will be 134.1 megawatts as determined below:

Hydro Capacity (1964)	112.7 MW
Steam and Diesel (1964)	25.4 MW
Steam to be Added in 1965	11.5 MW
Total	149.6 MW
Less Largest Unit	15.5 MW
Firm Capacity	134.1 MW

It will be observed in Table X that the expected load in 1968 is 136.1 megawatts. This is in excess of the above firm capacity and indicates that plant additional to that now operating, under construction or authorized, should be ready for operation before the 1968 peak.

The above 1967 capacity of 149.6 megawatts includes the 7.5-megawatt NATO plant (which is maintained ready for immediate operation in any emergency) and, as indicated, a 11.5-megawatt steam unit that the Reykjavik Municipality plans to install in 1965.

It is to be observed that the Ljosafoss hydro station on the Sog can be expanded to accommodate an additional generating unit. This will certainly be done in the future at the most suitable time.

It is concluded that the SW-N integrated system will require additional generating capacity by 1968 without which the estimated maximum demand will exceed the then firm capability of the system. The forecasted load increase for the following five years is approximately 55.0 megawatts, in addition to a potential demand of 55.0 megawatts for the proposed aluminum plant.

Based on the assumptions that: (1) construction of the Burfell Project is started as soon as possible; (2) a SW-N intertie is constructed for operation after the completion of the first stage of the Burfell Project, and (3) a one potline aluminium plant is established and ready for operation on completion of the first stage of Burfell, a possible plan for capacity additions is shown graphically with the forecasted SW-N integrated system demand curve in Exhibit 6-A.

The firm capacity is considered as the installed capacity of all generating plants less the rated capacity of the system's largest unit, a common practice in studies of this type. On this basis a 35-megawatt unit at Burfell represents a rather conservative approach, approximately 20 percent of the 1968 load. On the other hand, consideration of the more costly to operate steam and diesel units as reserves would be approximately as great.

On Exhibit 6-B is plotted the forecasted requirements of energy production to supply the SW-N integrated system primary load; on the same Exhibit is also shown the system hydro capability in an average water year. The latter is observed to be considerably in excess of the production requirements, after the Burfell Project is operating.

Exhibit 6-A is complementary to the Power Market Study and shows when new generating capacity on the SW-N integrated system is required, plus a logical installation schedule in connection with the proposed Burfell Project. Exhibit 6-B is complementary to Exhibit 6-A and shows that the suggested capacity addition program designed to meet the maximum primary demand requirements of the integrated system would definitely meet the primary energy requirements as well.

THE EXHIBITS

LIST OF EXHIBITS

Exhibit No.

1. Inhabited Areas of Iceland and Degree of Electrification

2. Population, Electrical Energy Production and Consumption Per Capita

3. Electric Utilities - State and Municipal

4. Power Stations, Transmission Lines and Main Sub-Stations

5. Possible Future Interconnections

6-A (SW-N) Integrated System; Forecasted Demand and Possible Plant Installation Schedule

6-B (SW-N) Integrated System; Forecasted Energy Production Requirements and Average Hydro Capability

Exhibit 1

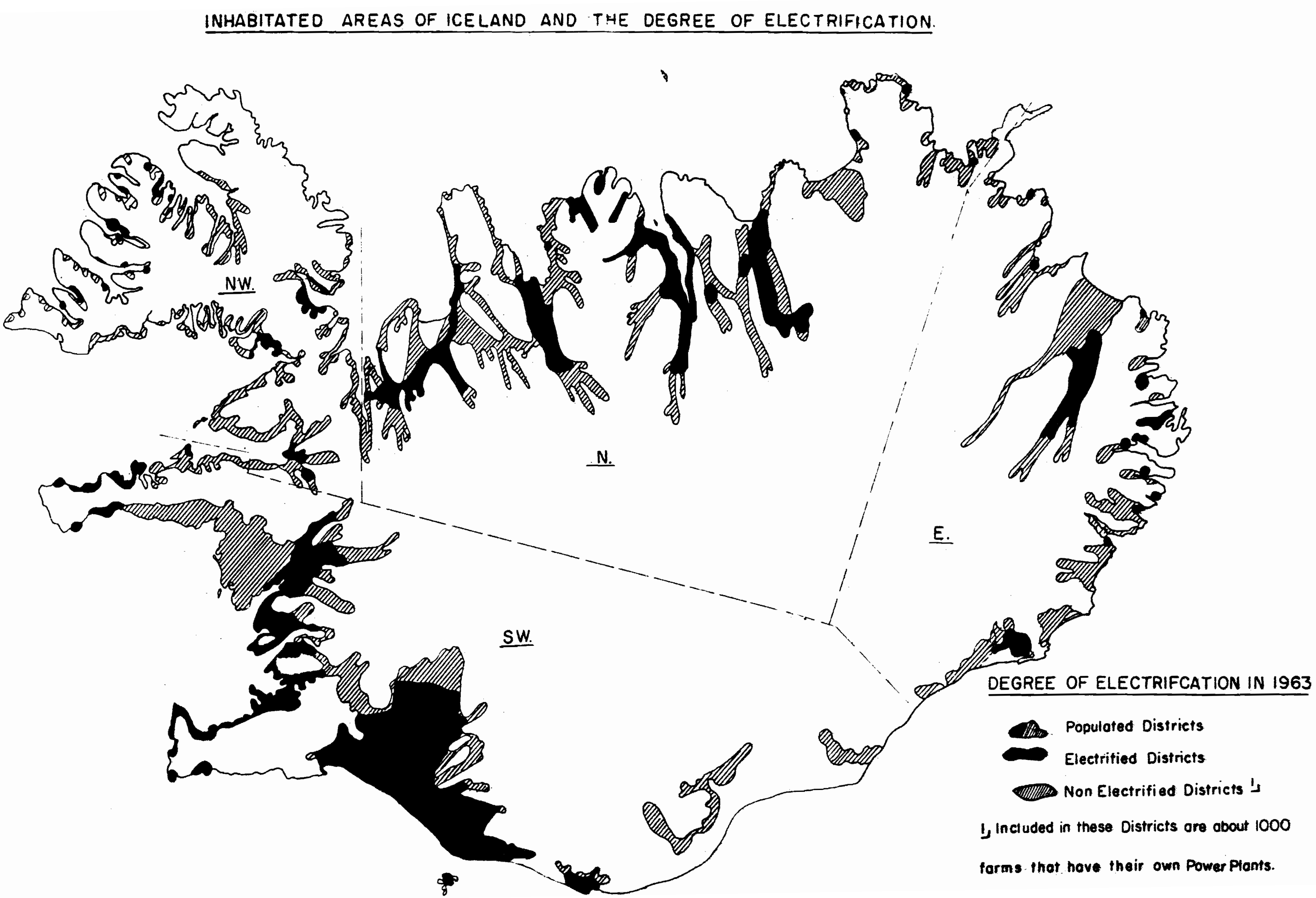

INHABITATED AREAS OF ICELAND AND THE DEGREE OF ELECTRIFICATION.
NW.
N.
E.
SW.
DEGREE OF ELECTRIFCATION IN 1963
Populated Districts
Electrified Districts
Non Electrified Districts 1)
1) Included in these Districts are about 1000 farms that have their own Power Plants.

Exhibit 2

POPULATION, ELECTRICAL ENERGY PRODUCTION AND ELECTRICITY CONSUMPTION PER CAPITA IN ICELAND

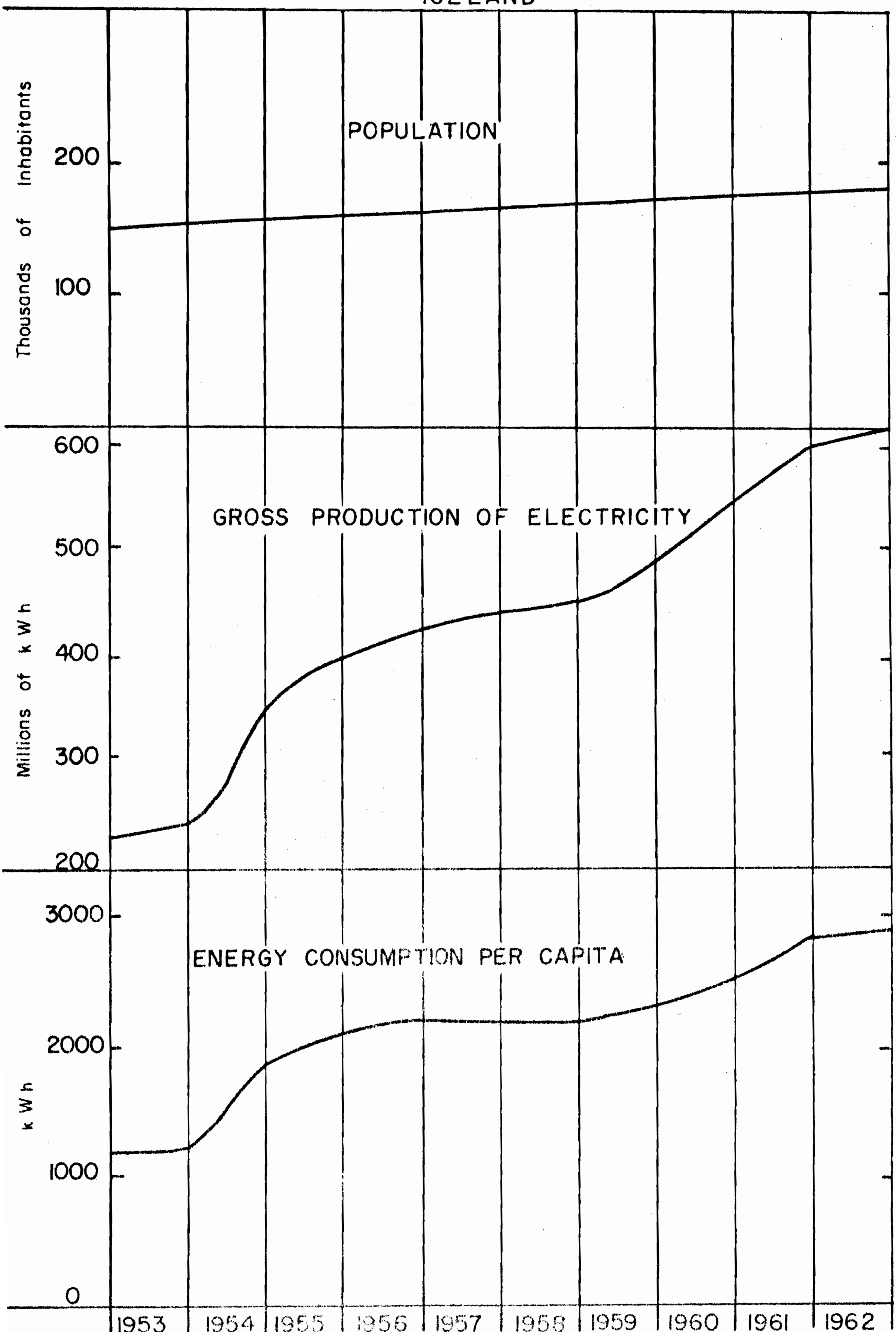


Exhibit 3.

ELECTRIC UTILITIES IN ICELAND - STATE AND MUNICIPAL

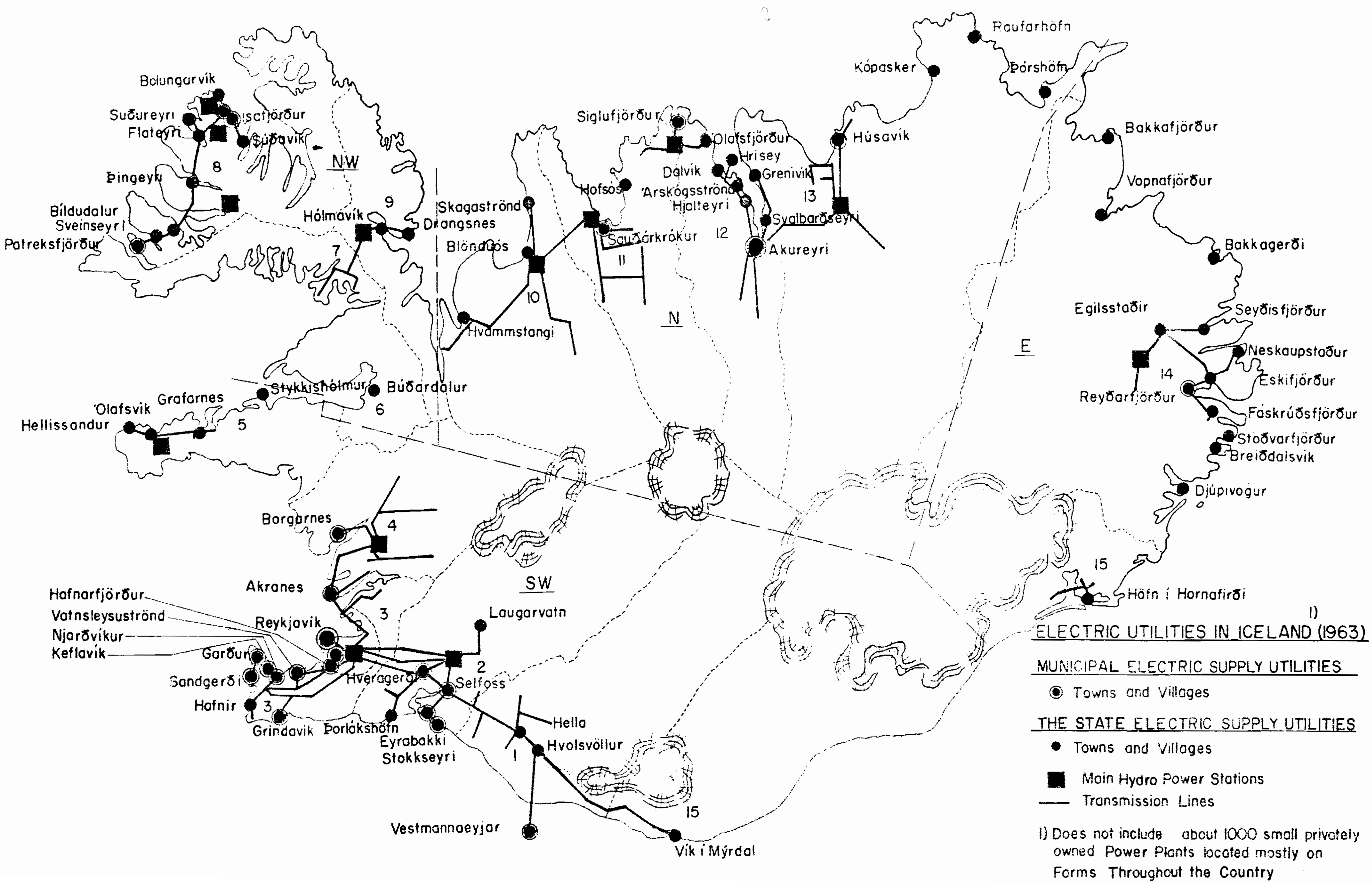


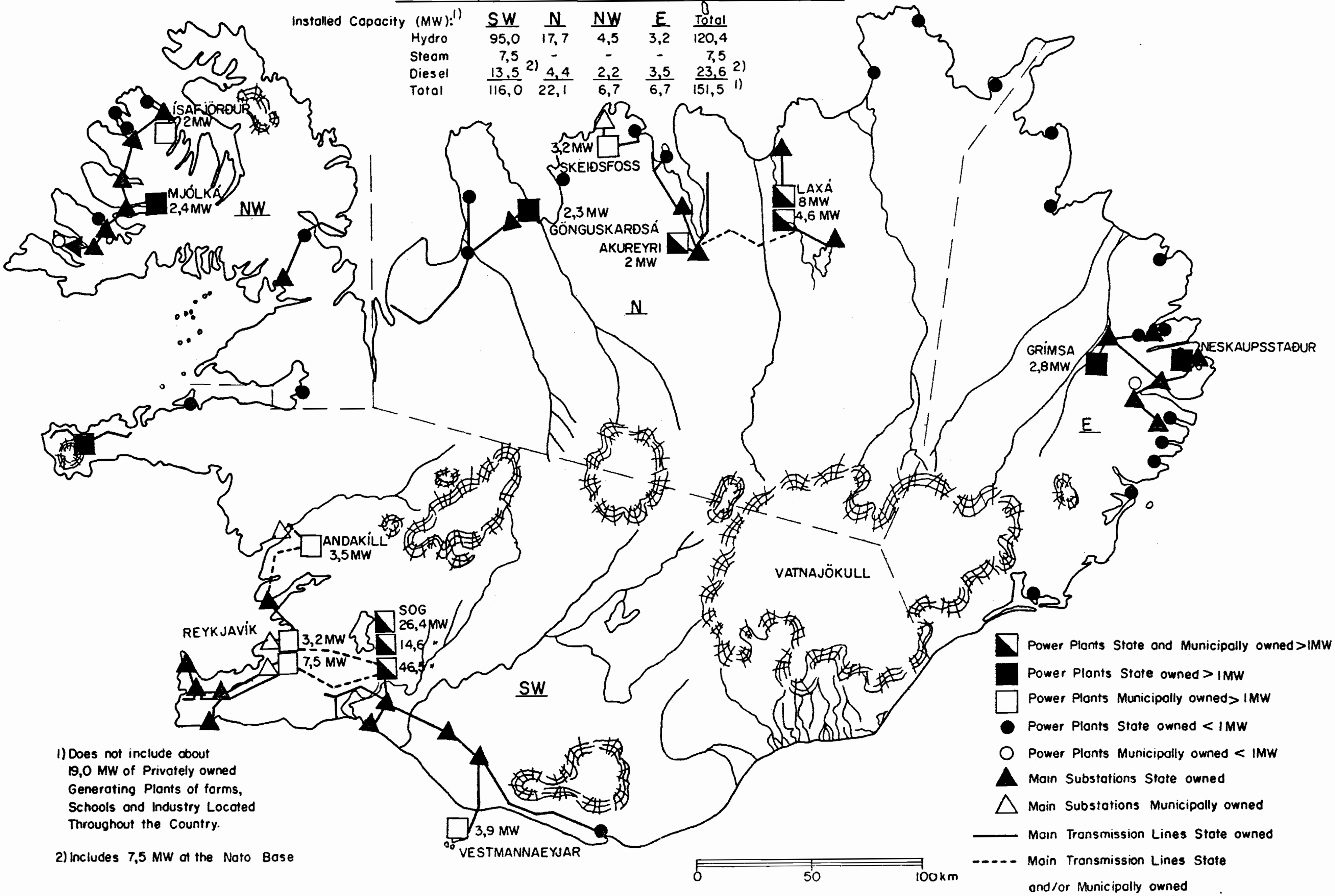
Exhibit 4.

POWER STATIONS, TRANSMISSION LINES AND MAIN SUBSTATIONS IN ICELAND

(LOCATION, OWNERSHIP AND CAPACITY - YEAR END 1963)

Installed Capacity (MW):1)

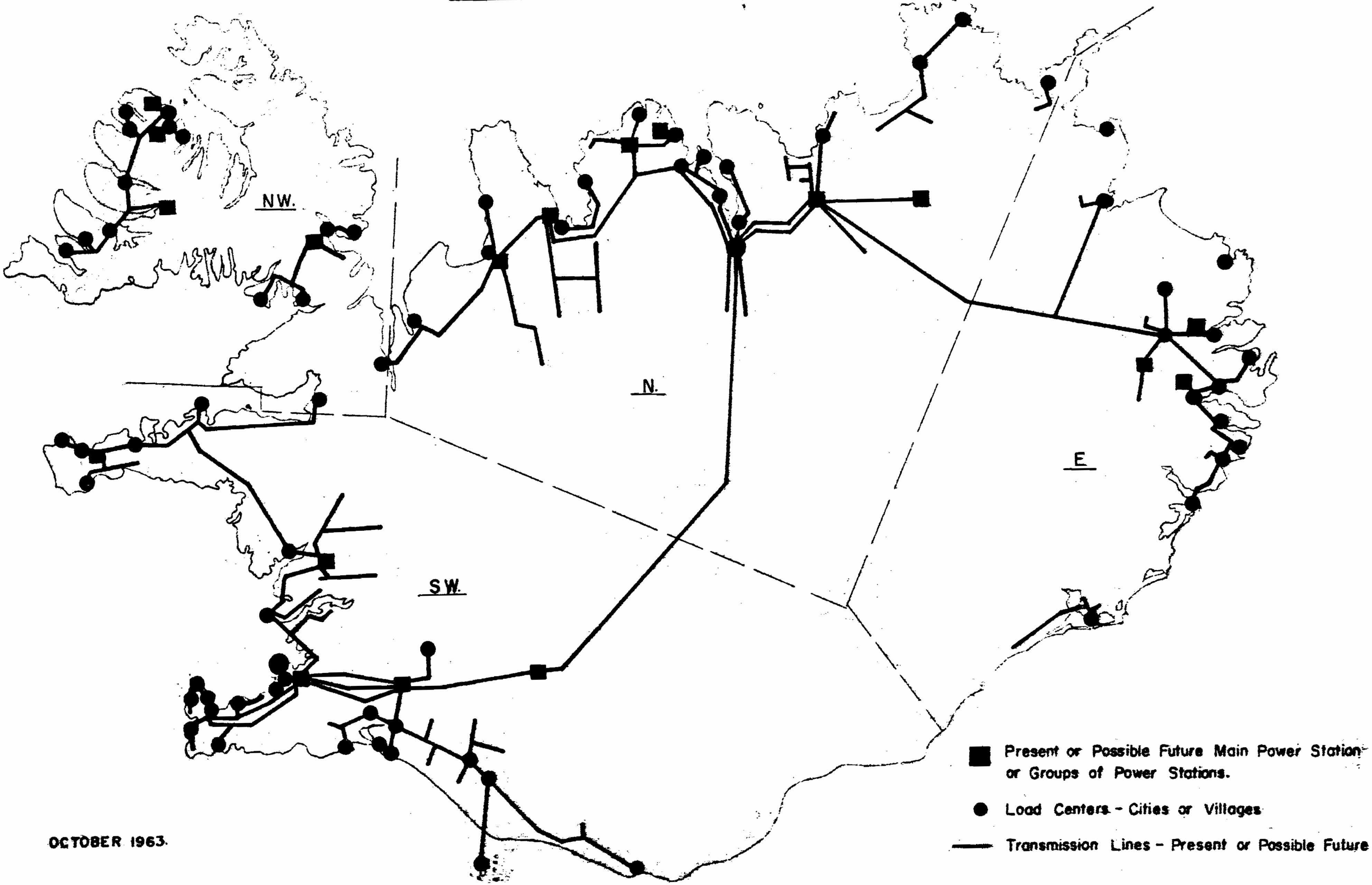
	SW	N	NW	E	Total
Hydro	95,0	17,7	4,5	3,2	120,4
Steam	7,5 2)	-	-	-	7,5 2)
Diesel	13,5	4,4	2,2	3,5	23,6
Total	116,0	22,1	6,7	6,7	151,5 1)



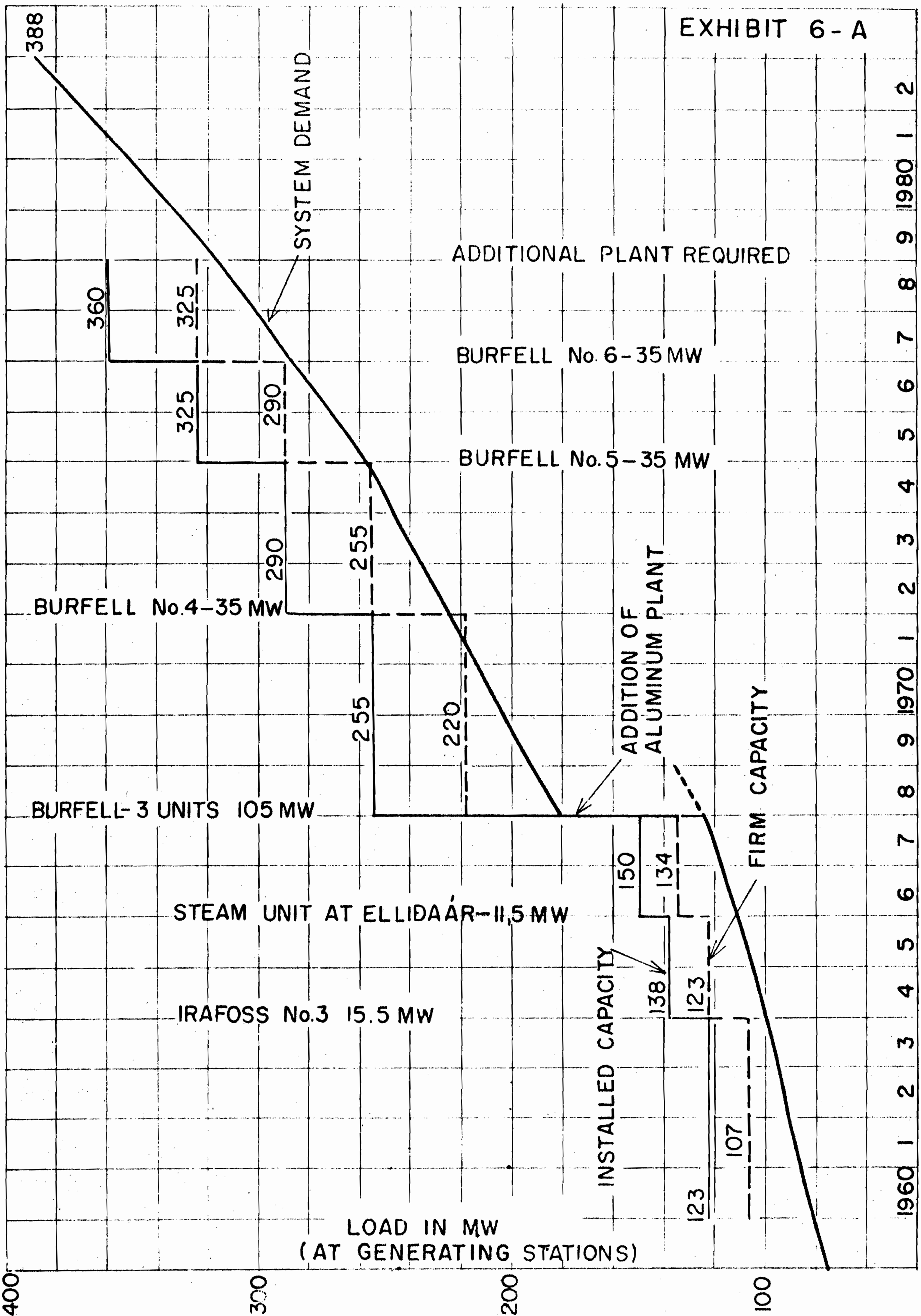
1) Does not include about 19,0 MW of Privately owned Generating Plants of farms, Schools and Industry Located Throughout the Country.

2) Includes 7,5 MW at the Nato Base

POSSIBLE FUTURE INTERCONNECTIONS WITHIN AND BETWEEN THE VARIOUS POPULATED AREAS OF ICELAND.

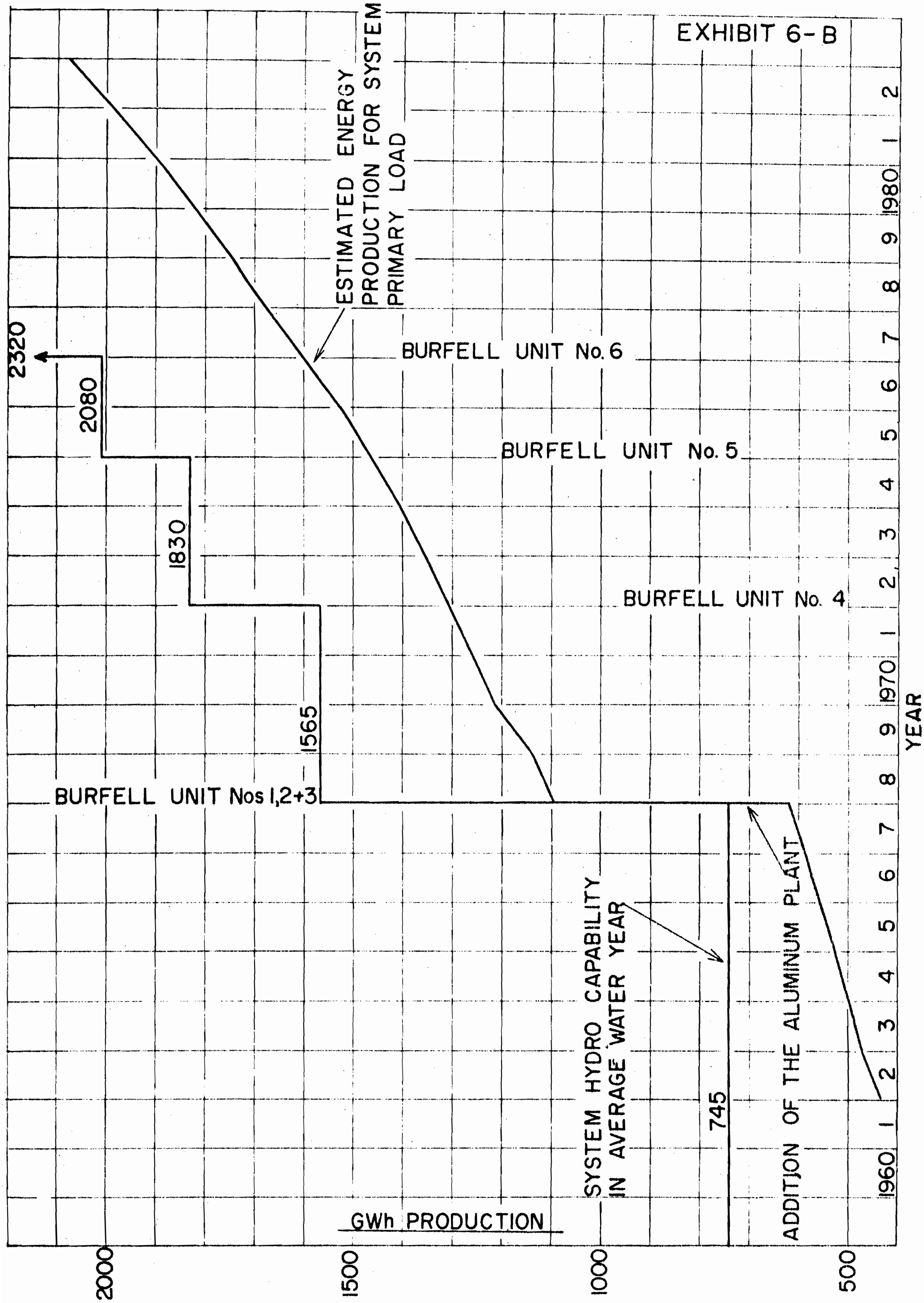


OCTOBER 1963.



HARZA ENGINEERING COMPANY INTERNATIONAL	ESTIMATED LOADS AND RESOURCES SW-N INTEGRATED SYSTEM ICELAND.	POWER MARKET SURVEY Nov. 9. 1963

EXHIBIT 6-B



HARZA ENGINEERING COMPANY INTERNATIONAL

EST. ENERGY REQUIREMENTS AND AVERAGE HYDRO RESOURCES SW-N INTEGRATED SYSTEM ICELAND

POWER MARKET SURVEY
Nov. 9, 1963

THE TABLES

LIST OF TABLES

Table	
I	Southwest - Statistics of Energy Consumption
II	Southwest - Load Statistics
III	Southwest - Actual and Projected Energy Production, Maximum Demand and Load Factor
IV	North - Statistics of Electricity Consumption and Production
V	North - Actual and Projected Electricity Sales, Production and Load Factor
VI	Northwest - Statistics of Electricity Consumption and Production
VII	Northwest - Actual and Projected Electricity Sales, Production and Load Factor
VIII	East - Statistics of Electricity Consumption and Production
IX	East - Actual and Projected Electricity Sales, Production and Load Factor
X	Southwest - North Integrated System; Forecast of Energy Production, Maximum Demand and Load Factor

TABLE I.

STATISTICS OF ELECTRICITY CONSUMPTION - SOUTHWEST AREA

(CONSUMERS OTHER THAN NATO AND THE FERTILIZER PLANT)

YEAR	ENERGY CONSUMED IN MILLIONS OF KWH						
	DOMESTIC	SPACE HEATING	COMMERCIAL	INDUSTRIAL	PUBLIC LIGHTING	OTHER	TOTAL
1952	48.893	23.067	7.754	28.780	2.693	13.521	124.708
1953	50.461	29.230	8.369	31.211	2.891	9.824	131.986
1954	55.859	36.082	9.992	36.082	3.144	7.630	148.789
1955	59.079	38.290	11.264	38.125	3.508	8.751	159.017
1956	63.611	40.141	12.739	42.214	3.799	10.018	172.522
1957	64.732	40.705	13.483	42.817	4.538	8.516	174.791
1958	70.179	42.956	14.951	52.090	4.395	10.124	194.695
1959	69.915	45.150	17.129	66.169	5.687	6.666	210.716
1960	70.622	44.702	16.730	68.528	6.067	12.128	218.777
1961	79.266	47.759	19.839	67.039	7.510	15.650	237.063

TABLE II

LOAD STATISTICS SOUTHWEST AREA

YEAR	TOTAL PRODUCTION ENERGY (GWH)	TOTAL PRODUCTION DEMAND (MW)	PRODUCTION FOR: NATO (GWH)	PRODUCTION FOR: FERT. (GWH)	PRODUCTION FOR: TOTAL (GWH)	COINCIDENT DEMAND OF: NATO (MW)	COINCIDENT DEMAND OF: FERT. (MW)	COINCIDENT DEMAND OF: TOTAL (MW)	PRODUCTION FOR ORDINARY CONSUMERS (GWH)	PRODUCTION FOR ORDINARY CONSUMERS (MW)	LOAD FACTOR (%)
1952	165.0								165.C		
1953	176.0			1.1	1.1				174.9		
1954	283.0			92.5	92.5				190.5		
1955	328.0			123.1	123.1				204.9		
1956	350.0			132.0	132.0				218.0		
1957	355.0			126.7	126.7				228.3		
1958	365.0	63.2		111.9	111.9		3.8	3.8	253.1	59.4	48.7
1959	395.0	67.6		112.8	112.8		4.3	4.3	282.2	63.3	51.0
1960	443.0	84.9	15.0	143.5	158.5	5.1	15.3	20.4	284.5	64.5	50.4
1961	484.0	85.4	38.4	152.4	190.8	5.4	13.2	18.6	293.2	66.8	50.0
1962	492.0	81.7	42.2	134.5	176.7	6.2	6.3	12.5	315.3	69.2	52.0

NOTE: THE MISSING FIGURES WERE NOT READILY AVAILABLE

TABLE III

SOUTHWEST AREA

ACTUAL AND PROJECTED ENERGY PRODUCTION, MAXIMUM DEMAND AND LOAD FACTOR

	PRODUCTION FOR ORDINARY LOAD			PRODUCTION FOR 4) NATO		PRODUCTION FOR PRIMARY FERTILIZER LOAD		ESTIMATED PRODUCTION FOR PRIMARY LOAD		
	GWH	MAX.DEMAND (MW)	LOAD FACTOR (%)	GWH	MAX. MW	3) GWH	MAX MW	GWH	MAX. MW	LOAD FACTOR (%)
1958	253.1	59.4	48.7	-	-	29.0	3.3	282.1	62.7	51.4
1959	282.2	63.3	51.0	-	-	29.0	3.3	311.2	66.6	53.2
1960	284.5	64.5	50.4	15.0	5.1	29.0	3.3	328.5	72.9	51.5
1961	293.2	66.8	50.0	38.5	5.4	29.0	3.3	360.7	75.5	54.5
1962 5)	315.3	69.2	52.0	42.2	6.2	29.0	3.3	386.5	78.7	56.1
1963	337.3	73.3	52.5	46.2	6.5	29.0	3.3	412.5	83.1	56.6
1964	357.7	77.6	52.5	49.5	6.5	29.0	3.3	436.2	87.4	57.0
1965	379.5	82.5	52.5	51.6	6.5	29.0	3.3	460.1	92.3	57.0
1966	402.9	87.5	52.5	52.8	6.5	29.0	3.3	484.7	97.3	57.0
1967	427.9	93.2	52.5	58.5	6.5	29.0	3.3	515.4	103.0	57.0
1968	457.9	99.6	52.5	69.0	1) 10.4	29.0	3.3	555.9	113.3	56.0
1969	489.9	106.2	52.5	73.4	11.2	58.0	2) 6.7	621.3	124.1	57.0
1970	524.1	114.0	52.5	77.7	11.8	58.0	6.7	659.8	132.5	56.8
1971	560.7	122.0	52.5	82.3	12.6	58.0	6.7	701.0	141.3	56.6
1972	599.9	130.3	52.5	85.5	12.9	58.0	6.7	743.4	149.9	56.7
1973	641.8	139.6	52.5	88.3	12.9	58.0	6.7	788.1	159.2	56.6
1974	686.6	149.2	52.5	94.5	12.9	58.0	6.7	839.1	168.8	56.7
1975	734.6	159.6	52.5	97.3	12.9	58.0	6.7	889.9	179.2	56.7
1976	785.9	171.0	52.5	97.3	12.9	87.0	2) 10.0	970.2	193.9	57.4
1977	840.9	183.0	52.5	97.3	12.9	87.0	10.0	1025.2	205.9	57.0
1978	899.7	195.8	52.5	97.3	12.9	87.0	10.0	1084.0	218.7	56.5
1979	962.7	209.5	52.5	97.3	12.9	87.0	10.0	1147.0	232.4	56.3
1980	1030.0	224.0	52.5	97.3	12.9	87.0	10.0	1214.3	246.9	56.2
1981	1102.0	240.0	52.5	97.3	12.9	87.0	10.0	1286.3	262.9	55.8
1982	1179.2	256.0	52.5	97.3	12.9	87.0	10.0	1363.5	278.9	55.8

1) ASSUMED THAT THE SECOND FREQUENCY CHANGER WOULD BE INSTALLED DURING 1967
2) ASSUMED THAT THE FERTILIZER PLANT CAPACITY WOULD BE DOUBLED DURING 1968 AND TREBLED DURING 1975
3) NOT NECESSARILY THE PRIMARY BUT THE MAXIMUM TO WHICH THE FERTILIZER FACTORY WOULD BE ENTITLED UNDER THE PRIMARY POWER CONTRACT
4) THE FERTILIZER PLANT WOULD TAKE SECONDARY LOAD IN ADDITION; TO THE EXTENT AVAILABLE.
5) ALL FIGURES FOR 1963 AND SUBSEQUENT YEARS ARE ESTIMATED.

TABLE III

TABLE IV

STATISTICS OF ELECTRICITY CONSUMPTION AND PRODUCTION - NORTHERN AREA

YEAR	ENERGY CONSUMED IN MILLIONS OF KWH							TOTAL PRODUCTION (GWH)	LOSSES PLUS STAT.USE (%)	MAX. DEMAND (MW)	LOAD FACTOR (%)
	DOMESTIC	SPACE HEATING	COMMER-CIAL	INDUST-RIAL	PUBLIC LIGHTING	OTHER	TOTAL				
1952	12.752	14.256	.795	2.349	.571	1.289	32.012	41.000	21.9	7.0	66.7 [1)]
1953	11.241	15.723	.945	3.565	.415	1.061	32.950	43.000	23.2	8.0	61.4
1954	12.502	17.984	1.006	5.242	.389	1.185	38.308	46.000	16.8	10.3	50.9
1955	12.114	21.036	1.057	5.012	.431	1.323	40.973	51.000	19.6	10.4	56.0
1956	12.029	22.588	1.228	5.506	.541	1.231	43.123	55.000	21.6	11.4	55.0
1957	13.238	24.313	1.391	6.578	.605	1.198	47.323	59.000	19.8	12.7	53.0
1958	14.314	25.491	1.647	8.554	.657	1.327	51.990	64.000	18.8	13.5	54.0
1959	14.850	25.844	1.806	9.346	.847	1.577	54.270	67.000	19.0	13.8	55.4
1960	19.235	24.586	1.503	8.236	.774	2.728	57.062	68.000	16.2	14.7	52.6
1961	18.210	24.928	1.624	10.089	1.076	4.719	60.646	75.000	19.2	15.4	55.6

1) THE LOAD FACTOR IN 1952 AND 1953 WAS INFLATED DUE TO ABNORMAL OPERATING CONDITIONS

TABLE V

NORTHERN AREA

ACTUAL AND PROJECTED ELECTRICITY SALES, PRODUCTION AND LOAD FACTOR

YEAR	ENERGY SALES (GWH)	ENERGY PRODUCTION (GWH)	MAXIMUM DEMAND (MW)	LOAD FACTOR (%)
1958	51.990	64.0	13.5	54.0
1959	54.270	67.0	13.8	55.4
1960	57.062	68.0	14.7	52.6
1961	60.646	75.0	15.4	55.6
1962	65.900	83.0	15.8	60.0
1963[1)]	69.300	85.1	16.3	59.5
1964	73.800	90.5	17.4	59.0
1965	78.500	96.4	18.8	58.5
1966	83.200	102.2	20.1	58.0
1967	88.000	108.0	21.4	57.5
1968	92.800	113.8	22.8	57.0
1969	98.600	121.0	24.4	56.5
1970	103.400	126.8	25.8	56.0
1971	109.300	134.2	27.6	55.5
1972	115.500	141.8	29.4	55.0
1973	122.000	149.8	31.4	54.5
1974	129.000	158.4	33.5	54.0
1975	136.500	167.6	35.8	53.5
1976	144.400	177.1	38.2	53.5
1977	152.900	187.5	40.4	53.0
1978	161.800	198.5	42.7	53.0
1979	171.400	210.2	45.3	53.0
1980	181.500	222.5	48.0	53.0
1981	192.500	236.0	50.8	53.0
1982	204.100	251.3	54.0	53.0

[1)] All figures for 1963 and subsequent years are estimated

TABLE VI

STATISTICS OF ELECTRICITY CONSUMPTION AND PRODUCTION - NORTHWEST AREA

YEAR	ENERGY CONSUMED IN MILLIONS OF KWH							TOTAL PRODUCTION (GWH)	LOSSES PLUS STAT. USE (%)	MAX. DEMAND (MW)	LOAD FACTOR (%)
	DOMESTIC	SPACE HEATING	COMMER-CIAL	INDUST-RIAL	PUBLIC LIGHTING	OTHER	TOTAL				
1952	2.373	.006	.374	1.103	.163	.290	4.309	5.000		2.0	28.5
1953	2.302	.187	.369	1.205	.156	.258	4.477	6.000		2.1	32.6
1954	2.606	.269	.366	1.533	.192	.324	5.310	6.000		2.3	29.8
1955	2.672	.350	.420	2.016	.171	.354	5.983	6.000		2.3	29.8
1956	2.942	.127	.472	1.732	.210	.403	5.886	7.000		2.5	32.0
1957	2.944	.164	.459	1.843	.194	.347	5.951	7.000		2.6	30.7
1958	3.415	.254	.667	2.889	.198	1.353	8.776	9.000		2.7	38.1
1959	4.029	.307	.381	3.889	.297	1.503	10.406	12.000		3.3	41.5
1960	4.423	.221	.442	4.850	.286	.261	10.483	15.000		4.0	42.7
1961	4.741	.217	.465	6.008	.331	.402	12.164	17.000		4.2	46.2
AVERAGE									18.1		

TABLE VII

NORTHWESTERN AREA

ACTUAL AND PROJECTED SALES, PRODUCTION AND LOAD FACTOR

YEAR	ENERGY SALES (GWH)	ENERGY PRODUCTION (GWH)	MAXIMUM DEMAND (MW)	LOAD FACTOR (%)
1958	8.776	9.0	2.7	38.1
1959	10.406	12.0	3.3	41.5
1960	10.483	15.0	4.0	42.7
1961	12.164	17.0	4.2	46.2
1962	14.000	18.0	4.5	45.7
1963[1)]	15.800	19.8	4.9	46.0
1964	17.600	22.0	5.4	46.5
1965	19.400	24.2	5.9	47.0
1966	21.200	26.5	6.3	47.5
1967	23.000	28.8	6.9	47.5
1968	24.800	31.0	7.4	47.5
1969	26.600	33.2	8.0	47.5
1970	28.400	35.5	8.5	47.5
1971	30.200	38.8	9.3	47.5
1972	32.100	40.2	9.7	47.5
1973	34.000	42.5	10.2	47.5
1974	35.800	44.7	10.7	47.5
1975	37.600	47.0	11.3	47.5
1976	39.400	49.2	11.8	47.5
1977	41.200	51.5	12.4	47.5
1978	43.000	53.7	12.9	47.5
1979	44.800	56.0	13.5	47.5
1980	46.600	58.3	14.0	47.5
1981	48.500	60.6	14.6	47.5
1982	50.400	62.8	15.1	47.5

[1)] Figures for 1963 and subsequent years are estimated

TABLE VIII

STATISTICS OF ELECTRICITY CONSUMPTION AND PRODUCTION-EASTERN AREA

YEAR	ENERGY CONSUMED IN MILLIONS OF KWH							TOTAL PRODUCTION (GWH)	LOSSES + STA. USE (%)	MAX DEMAND (MW)	LOAD FACTOR (%)
	DOMESTIC	SPACE HEATING	COMMER-CIAL	INDUST-RIAL	PUBLIC LIGHTING	OTHER	TOTAL				
1952	2.078	.343	.181	.717	.094	-	3.413	4.0		1.3	35.2
1953	2.239	.306	.183	.759	.084	.244	3.815	4.0		1.3	35.2
1954	2.150	.200	.189	1.063	.101	.218	3.921	4.0		1.4	32.6
1955	2.180	.171	.205	1.365	.107	.232	4.260	5.0		1.4	40.7
1956	2.100	.143	.214	1.585	.107	.307	4.456	5.0		1.4	40.7
1957	1.795	.120	.191	1.615	.092	.178	3.991	6.0		1.6	42.8
1958	1.900	.120	.205	2.050	.094	.205	4.574	8.0		2.3	39.7
1959	3.060	.185	.342	3.180	.143	.212	7.122	10.0		2.8	40.7
1960	3.200	.194	.358	3.320	.149	.231	7.452	10.0		3.1	36.8
1961	3.762	.224	.422	3.876	.177	.260	8.721	12.0		3.3	41.5
AVERAGE									24.0		

TABLE IX

EASTERN AREA

ACTUAL AND PROJECTED ELECTRICITY SALES, PRODUCTION AND LOAD FACTOR

YEAR	ENERGY SALES (GWH)	ENERGY PRODUCTION (GWH)	MAXIMUM DEMAND (MW)	LOAD FACTOR (%)
1958	4.6	8.0	2.3	39.7
1959	7.1	10.0	2.8	40.7
1960	7.5	10.0	3.1	36.8
1961	8.7	12.0	3.3	41.5
1962	9.9	13.0	3.9	38.0
1963[1]	11.1	14.8	4.3	39.0
1964	12.3	16.4	4.7	40.0
1965	13.6	18.1	5.0	41.0
1966	15.0	20.0	5.4	42.0
1967	17.4	23.2	6.1	43.0
1968	19.1	25.5	6.6	44.0
1969	20.9	27.8	7.0	45.0
1970	22,9	30.5	7.7	45.0
1971	25.0	33.4	8.5	45.0
1972	27.4	36.5	9.3	45.0
1973	29.9	39.9	10.1	45.0
1974	32.6	43.5	11.0	45.0
1975	35.6	47.5	12.0	45.0
1976	38.5	51.4	13.0	45.0
1977	41.5	55.4	14.0	45.0
1978	44.4	59.3	15.0	45.0
1979	47.4	63.3	16.1	45.0
1980	50.5	67.4	17.1	45.0
1981	53.9	71.8	18.2	45.0
1982	57.5	76.7	19.4	45.0

1) All figures for 1963 and subsequent years are estimated.

TABLE X

ELECTRIC SYSTEMS OF THE SOUTHWEST AND NORTHERN AREAS INTEGRATED
ESTIMATED ENERGY PRODUCTION, MAXIMUM DEMAND AND LOAD FACTOR

Year	SW AREA PRIMARY PROD. (GWH)	SW AREA PRIMARY MAX.DEM. (MW)	N AREA PROD. (GWH)	N AREA MAX.DEM. (MW)	COIN-CIDENT MAX.DEM.	COMBINED AREAS GWH	COMBINED AREAS MAX. DEMAND (MW)	LOAD FACTOR (%)	ALUMINUM FACTORY GWH	ALUMINUM FACTORY MW	COMBINED LOAD GWH	COMBINED LOAD MAX. DEMAND (MW)	LOAD FACTOR (%)
1958	282.1	62.7	64.0	13.5	13.5	346.1	76.2	51.9	-	-	346.1	76.2	51.9
1959	311.2	66.6	67.0	13.8	13.8	378.2	80.4	53.8	-	-	378.2	80.4	53.8
1960	328.5	72.9	68.0	14.7	14.7	396.5	87.6	51.8	-	-	396.5	87.6	51.8
1961	360.7	75.5	75.0	15.4	15.4	435.7	90.9	54.7	-	-	435.7	90.9	54.7
1962	386.5	78.7	83.0	15.8	15.8	469.5	94.5	56.6	-	-	469.5	94.5	56.6
1963	412.5	83.1	85.1	16.3	16.3	497.6	99.4	57.2	-	-	497.6	99.4	57.2
1964	436.2	87.4	90.5	17.4	17.4	526.7	104.8	57.3	-	-	526.7	104.8	57.3
1965	460.1	92.3	96.4	18.8	18.8	556.5	111.1	57.2	-	-	556.5	111.1	57.2
1966	484.7	97.3	102.2	20.1	20.1	586.9	117.4	57.1	-	-	586.9	117.4	57.1
1967	515.4	103.0	108.0	21.4	21.4	623.4	124.4	57.1	-	-	623.4	124.4	57.1
1968	555.9	113.3	113.8	22.8	22.8	669.7	136.1	57.1	470.0	55.0	1139.7	191.1	68.0
1969	621.3	124.1	121.0	24.4	24.4	742.3	148.5	57.1	470.0	55.0	1212.3	203.5	68.0
1970	659.8	132.5	126.8	25.8	25.8	786.6	158.3	56.6	470.0	55.0	1256.6	213.3	67.2
1971	701.0	141.3	134.2	27.6	27.6	835.2	168.9	56.5	470.0	55.0	1305.2	223.9	66.5
1972	743.4	149.9	141.8	29.4	29.4	885.2	179.3	56.4	470.0	55.0	1355.2	234.3	66.0
1973	788.1	159.2	149.8	31.4	31.4	937.9	190.6	56.3	470.0	55.0	1407.9	245.6	65.5
1974	839.1	168.8	158.4	33.5	33.5	997.5	202.3	56.2	470.0	55.0	1467.5	257.3	65.0
1975	889.9	179.2	167.6	35.8	35.8	1057.5	215.0	56.2	470.0	55.0	1527.5	270.0	64.5
1976	970.2	193.9	177.1	38.2	38.2	1147.3	232.1	56.3	470.0	55.0	1617.3	287.1	64.1
1977	1025.2	205.9	187.5	40.4	40.4	1212.7	246.3	56.2	470.0	55.0	1682.7	301.3	63.7
1978	1084.0	218.7	198.5	42.7	42.7	1282.5	261.4	56.2	470.0	55.0	1752.5	316.4	63.2
1979	1147.0	232.4	210.2	45.3	45.3	1357.2	277.7	55.8	470.0	55.0	1827.2	332.7	62.7
1980	1214.3	246.9	222.5	48.0	48.0	1436.8	294.9	55.6	470.0	55.0	1906.8	349.9	62.2
1981	1286.3	262.9	236.0	50.8	50.8	1522.3	313.7	55.5	470.0	55.0	1992.3	368.7	61.8
1982	1363.5	278.9	251.3	54.0	54.0	1614.8	332.9	55.4	470.0	55.0	2084.8	387.9	61.5